CORE-JetFuel

Coordinating research and innovation in the field of sustainable alternative fuels for aviation

Deliverable 3.9
Report on Stakeholder Workshop

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Report on Stakeholder Workshop of Working Group 2&3 on Conversion Technologies and Deployment

SUBMITTED VERSION 1.0

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Work Package 3: International Expert and Stakeholder Exchange
Work Package Leader: WIP Renewable Energies

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IFPEN – IFP Energies Nouvelles, France

WIP- WIP Renewable Energies, Germany

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WORKSHOP

Sustainable alternative aviation fuels – Innovative conversion technologies and deployment

1 June 2015 in Vienna, Austria

on the occasion of the 23rd European Biomass Conference & Exhibition (EUBCE 2015)

WORKSHOP SUMMARY

Workshop Background

This event was organised in the framework of the project CORE-JetFuel (www.core-jetfuel.eu) supported by the European Commission in the 7th Framework Programme. 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.

For a number of ecologic and economic reasons, the aviation industry is in great need for alternative fuels. Highly ambitious goals for the reduction of the sector's overall greenhouse gas emissions set from industry and politics imply sustainable alternative fuels as major contribution. To meet the high expectations research and innovation efforts are required in order to develop pathways for an economically feasible large-scale production of such fuels for aviation.

This event presented and discussed results from the CORE-JetFuel project with focus on innovative technologies and value chains towards a large-scale market up-take of alternative aviation fuels.

Workshop Organisation

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Workshop Summary

Presentations: R. Janssen, D. Rutz, WIP Renewable Energies, J. Michel, FNR

Panel discussion: A. Roth, Bauhaus Luftfahrt

Workshop Presentations

All presentations are available at the website: http://www.core-jetfuel.eu/nav/events2.aspx

WORKSHOP SUMMARY

Opening Session

The CORE-JetFuel Stakeholder Workshop "Sustainable Alternative Aviation Fuels - Innovative conversion technologies and deployment" on 1 June 2015 in Vienna was opened by **Rainer Janssen**, WIP Renewable Energies. This CORE-JetFuel event is a follow-up on the successful Sustainable Aviation Fuels Forum (SAFF) on 20-22 October 2014 in Madrid. Whereas the main topics discussed at the SAFF in Madrid were policies, feedstock and sustainability, the focus of this workshop in Vienna is on innovative conversion technologies and deployment of alternative aviation fuels.

Johannes Michel, coordinator of the CORE-JetFuel project, Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Germany presented an overview of activities and results of the CORE-JetFuel project. Mr. Michel first introduced to the auditorium the main objectives of the project, namely to:

- Coordinate initiatives, projects and results/data, helping in building relationships and public-private cooperation
- Identify needs in research, standardisation, innovation and policy measures at European level
- Independent mapping and assessment of R&D activities in this field with collection of the lessons learned

The CORE-JetFuel working methodology consists of ***collection*** (information gathering), ***mapping*** of data and results from identified projects, as well as ***analysis/evaluation*** of gathered information and mapped projects/technology pathways. Thereby, the analysis of alternative fuel technologies requires a multiple-criteria approach applying three key ("high-level") criteria for alternative jet fuels: Suitability (e.g. "Drop-in" capability), Scalability (e.g. production potential), and Sustainability (e.g. GHG Emission reduction potential).

After presenting intermediate project results with respect to the four thematic domains (feedstock & sustainability, conversion technologies, deployment & certification, policies & regulations), Mr. Michel highlighted the importance of international stakeholder exchange for the success of the CORE-JetFuel initiative. All workshop participants were cordially invited to join the fruitful discussions and contribute to a vivid exchange of ideas and knowledge within the present workshop.

As an introduction to the panel discussion on Technology Assessment, **Arne Roth**, Bauhaus Luftfahrt, Germany presented an overview on the CORE-JetFuel technology assessment methodology. This methodology consist of the selection of suitable criteria for evaluation, the definition of metrics and scoring in order to facilitate quantification of results, the comprehensive weighting of criteria, as well as the final multiple criteria assessment.

Relevant questions addressed in the framework of the technology assessment include future production potentials, environmental impacts, production costs, drop-in capability, and the current state of maturity of the technologies. Identified criteria for technology assessment thus comprise ***technical maturity*** (feedstock production maturity, conversion technology maturity), ***technical compatibility***, ***economic competitiveness***, ***global substitution potential***, ***impact on local biodiversity***, and ***GHG reduction potential***, with further criteria currently under discussion.

An overview of CORE-JetFuel criteria and metrics is presented in the table below:

Criterion	Metric	
Technical maturity	Technology Readiness Level	TRL (1-9)
Feedstock production maturity	Feedstock Readiness Level	FSRL (1-9)
Conversion technology maturity	Conversion Technology Readiness Level	CTRL (1-9)
Technical compatibility	Maximum blending ratio	$r_{Blend,Max}$ [%]
Economic competitiveness	WtT production costs relative to spot price in 2013	γ [%]
Global substitution potential	Production potential relative to demand in 2050	σ [%]
Impact on local biodiversity	Negative impact	Yes/No
GHG reduction potential	Specific lifecycle GHG emissions relative to conventional jet	ε [%]

Session 1 – Innovative Value Chains for Alternative Aviation Fuels

Patrick Biller, Energy Research Institute, University of Leeds, UK presented recent research results on hydrothermal liquefaction for the production of aviation fuels. Within hydrothermal liquefaction (HTL) processes biomass feedstock is *pressure cooked* in hot-compressed water allowing high moisture contents of the feedstock. Typically, hydrothermal processing takes place at temperatures of 250-350°C and pressures up to 180 bar. Products consist of bio-crude oil, syngas, residue (synthetic coal) and process water.

Wet biomass such as microalgae is ideally suited for HTL converting the whole algae to high energy density bio-crude oil. Microalgae contain oils (triglycerides), protein and carbohydrates and promise high yields due to their extremely high growth rates. Cultivation of microalgae does not require agricultural land, thus competition with food production is avoided. Finally, they are suitable for HTL due to their small size with no grinding required.

Research results from a continuous reactor (4l/h) operated at the University of Leeds show high yields of up to 40% of produced bio-crude oil with a Higher Heating Value (HHV) of 36 MJ/kg at optimum operating conditions. Chemical compounds present in the bio-crude have been extensively studied indicating detrimental contents of oxygen (~ 10%) and nitrogen (~ 6%). These impurity levels can be reduced below detectable limits with a subsequent hydro-treatment of the bio-crude-oil making the product a promising candidate for advanced biofuels including aviation fuels.

Currently, efforts in Whyalla, Australia include the cultivation of microalgae in a 0.4 ha pond and the operation of a pilot HTL plant (capacity: 3 t/d) for the production of ~10,000 litres of bio-crude oil per year. Further up-scaling is planned to a biomass to bio-crude production of 50 million litres per year in 2020.

In conclusion, Mr. Biller stated that hydrothermal processing is an ideal biofuel route for wet biomass, microalgae as well as macroalgae, as it requires no drying and promises high yields and good energy recovery in continuous processes. Until today, nitrogen levels in the bio-crude are a major challenge with hydrogenation of the bio-crude leading to fuels approaching fuel standards.

Xavier Dommange from Airbus Group Innovations, France gave a presentation on milestones for microalgae aviation fuels. Due to the anticipated growth of the aviation sector in the coming decades there will be a massive need for sustainable fuels in order to substitute fossil fuels and meet the environmental targets of the sector. Microalgae are appropriate long-term solutions for the production of sustainable fuels as they offer many advantages over terrestrial plants, such as limited land use impacts as well as high potential yields. Furthermore, Jet-A1 fuels produced from microalgae seem promising with regards to safety and environmental impacts, however improvements with respect to the energetic balance and significant costs reductions still need to be achieved.

Due to the multitude of options to cultivate and process microalgae as well as the more than 100,000 potential algae strains international coordination of R&D efforts is urgently needed. According to the French national study “Algogroup” investigating the potential of the algae sector for advanced biofuel production the energetic balance is not favourable at present (i.e. Energy Ratio (ER) = 1) while production costs are still too high. The following three milestones have been identified (as intermediate steps) in order to move towards pre-industrial development of microalgae aviation fuels:

- Milestone 1: Energy Ratio comparable to biodiesel and corn ethanol (ER = 1.3)
- Milestone 2: Costs per litre comparable to other biofuels
- Milestone 3: Energy Ratio comparable to sugarcane based fuels (ER = 5)

Mr. Dommange reported on a large number of activities to improve the Energy Ratio of microalgae aviation fuels. Prioritisation of R&D efforts are recommended in the fields of CO_2 feed design, light systems, culture system design, strain optimization, as well as process design and integration.

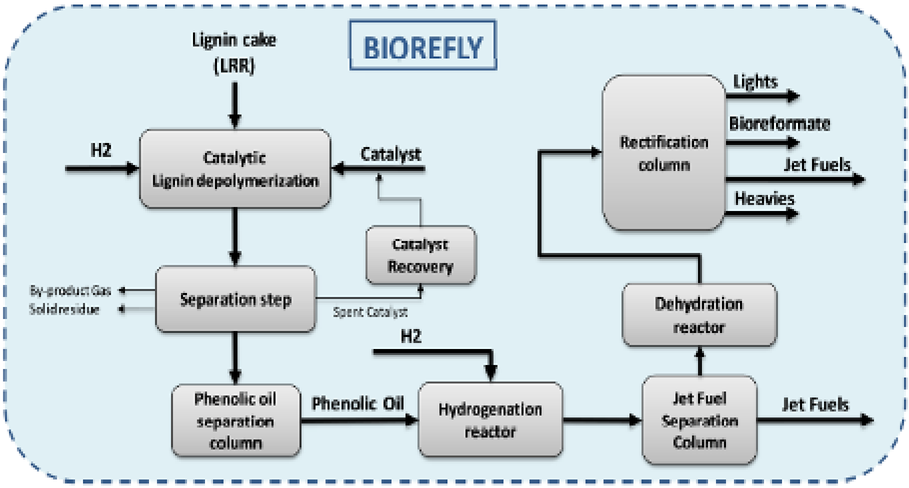
David Chiaramonti from the Renewable Energy COnsortium for R&D (RE-CORD), Italy presented an overview of the recently launched project BIOREFLY – Industrial Demonstration of Paraffinic Aviation Biofuels. BIOREFLY is co-funded by the European Commission in the 7th Framework Programme and aims at the industrial scale demonstration (capacity: 2,000 tons per year) of a biorefinery on lignin based aviation fuels. Activities performed in the framework of BIOREFLY include:

- Validation of novel competitive technologies for lignocellulosic-based aviation fuel production at pre-commercial scale
- Design, construction and operation of a first-of-a-kind industrial lignin based jet fuel production facility based on innovative second generation technologies
- Implementation of the full value chain including the production and conversion of lignocellulosic energy crops and agricultural residues
- Testing of aviation fuels in turbines and engines
- Implementation of test flights

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. The combined production of high annual volumes of cellulosic ethanol and lignin-based jet fuel through sustainable and innovative technologies will be an important step towards biofuel commercialisation and market deployment.

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.

The BIOREFLY process concept is shown in the graph below.



The BIOREFLY project is coordinated by BIOCHEMTEX, Italy and implemented in partnership with ETH Zürich, Switzerland, KLM, Netherlands, RE-CORD, Italy, SkyNRG, Netherlands, and WIP - Renewable Energies, Germany. More information of the project is available at www.biorefly.eu.

Johnathan Holladay from Pacific Northwest National Laboratory (PNNL), USA reported on recent jet fuel advances in bio-oil and alcohol upgrading. Mr. Holladay started his presentation with highlighting the properties of standard Jet A or JP-8 aviation fuels. Jet fuels have an ideal carbon length of C8 – C16 and consist of 70-85% paraffins (*n*-paraffins, *iso*-paraffins, cyclo-paraffins) and <25% aromatics. The content of olefins as well as S, N, and O containing compounds need to be kept below 5%. All alternative jet fuels approved today by ASTM are synthetic paraffinic kerosene (SPK), such as Fischer-tropsch (FT) fuels, hydroprocessed esters and fatty acids (HEFA), and direct sugar to hydrocarbon (DSHC) fuels.

In partnership with UOP, PNNL succeeded to produce the first pyrolysis based jet fuel which is currently on the ASTM testing pathway. Until today, significant technical challenges exist for the hydrotreating of pyrolysis oil with respect to sufficient catalyst bed stability as well as understanding the reasons for plug formation.

A technical solution found by PNNL to overcome catalysts deactivation is the integration of a low temperature (100-160°C) stabilization process prior to the hydrotreating (180-250°C) and hydrocracking (380-420°C) processes. It was shown that this stabilization process causes a reduction of certain aldehydes and residual sugars, and leads to a significant increase of catalyst bed stability facilitating more than 1,200 hours of continuous biomass hydrotreating on a single catalyst charge in a 1 t/d pyrolysis pilot plant. This achievement constitutes a significant step towards full scale commercialization of biomass hydrotreating technologies.

The measured product composition of the produced hydrotreated pyrolysis oil showed 7% paraffins, 47% cyclo-paraffins, and 46% aromatics. Thus, pyrolysis bio-oil and HTL bio-crude offer routes to the cyclic portion of renewable jet fuel, whereas the paraffinic portion needs to be produced via other pathways. Very active catalysts are required to remove residual sugars in pyrolysis bio-oil and current R&D goals include the development of non-carbon supporting metal catalysts with high activity, low coking rates and easy regeneration.

Panel Discussion on “Conversion Technologies and Deployment”

Moderation

- Arne ROTH, Bauhaus Luftfahrt

Panelists:

- David CHIARAMONTI, Re-Cord, Italy
- Inmaculada GOMEZ, SENASA, Spain
- John HOLLADAY, Pacific Northwest National Laboratory, USA
- Patrick BILLER, University of Leeds, UK
- Sierk DE JONG, SkyNRG, Netherlands
- Xavier DOMMANGE, Airbus Group Innovations, France

Aims and objectives

The development and commercialization of technologies for the conversion of various types of renewable feedstock are crucial in order to provide the large quantities of alternative fuels required by future aviation.

This panel discussion was based on the previous presentations on various kinds of conversion technologies and intended to continue the dialogue focused on the current state of development as well as the perspectives and key performance indicators of those technologies. Considering the variety of technologies currently under development (at different states of maturity), it is important to understand individual advantages, potentials, bottlenecks and drawbacks. It is also important to identify challenges and crucial steps associated with the technical certification of new or novel production fuel technologies on their way to commercialization. In this context, the main objective of this panel session was to learn the views of the panelists as renowned experts in their fields.

Panel agenda

1) ***Brief introduction of panelists***

2) ***Panel discussion on conversion technologies and deployment***

a) Large quantities of alternative fuels will be needed by the aviation sector. More than one single technology will be required for the production at industrial scale.
   - Which criteria are the most relevant for identifying technologies with highest potentials?
   - Which technologies are most suitable/promising for industrial implementation from a short-term (2020), medium-term (2035) and long-term (2050) perspective?
   - Which role do potential sustainable availability of required feedstock and flexibility in terms of feedstock types and sources play in this respect?

b) Conversion technologies for medium- or long-term application (with special, but not exclusive, focus on hydrothermal liquefaction and pyrolysis):
   - What are the current state of development and future perspectives of these technologies?
   - What are the technical bottlenecks? Can you specify key milestones/decision points for further development, e.g. in the form of a roadmap towards commercialization?

c) Deployment: Role of technical specification (ASTM)
   - What are the challenges and crucial steps with respect to ASTM certification for new or novel technologies on their way towards commercialization?

3) ***Plenary discussion***

4) ***Concluding panel discussion***

Panel Discussion Summary

Brief introduction of panelists

After a short introduction by the moderator, each panelist was invited to briefly present her/his organization and her/his vision on the current landscape and development of production technologies of renewable jet fuels.

Panel discussion on conversion technologies and deployment

Question a-1: Which criteria are the most relevant for identifying technologies with highest potentials?

David Chiaramonti

- Importance of feedstock availability at large scale and sustainability of feedstock.
- Production technology should be "built around" feedstock.
- HEFA is industrially available, but there are public concerns with respect to some types of feedstock such as palm oil. Sustainably produced lipids are limited in volume. Thus, lignocellulose based fuels may be more promising.

Xavier Dommange

- Safety: The most important feature of any type of bio-derived jet fuel is the safety of its utilization.
- Secondly, production potential is very important for alternative fuels, followed by their specific environmental and economic performance.
- Trade-offs are often observed between production potential as well as environmental and economic performance, thus a good balance is needed.

John Holladay

- Availability of sustainable low-cost feedstock is crucial.
- Conversion processes need to be efficient in terms of yields and energy ratio.
- The energy return on investment (EROI) is an important criterion.
- Reducing capital costs of commercialization projects is of crucial importance. Capital costs are responsible for recent failures of commercial-scale advanced biofuels plants (e.g. KiOR's Biomass Fluid Catalytic Cracking and Fischer-Tropsch processes). Thus, there is urgent need for (conversion) processes with controllable capital cost.

Question a-2: Which technologies are most suitable/promising for industrial implementation from a short-term (2020), medium-term (2035) and long-term (2050) perspective?

David Chiaramonti

- For short-term application the only available mature technology is HEFA.
- From medium- to long-term perspective, HTL (hydrothermal liquefaction) represents one of the most interesting conversion pathways.
- The overarching objective is to identify a feedstock which is continuously available (in large quantities and in wet form) for feeding plants / refineries.

Xavier Dommange

- Agrees that at present HEFA is the only available option.
- For medium-term application HTL (possibly using wet microalgal biomass as feedstock) is a promising option.
- Moving towards long-term implementation, non-biogenic pathways using carbon dioxide and water as feedstock (so-called reverse combustion technologies) become attractive, as pursued in the SOLAR-JET (FP7) project.

John Holladay

- Short term: Pyrolysis is available at commercial scale (UOP, Ensyn).
- For medium-term application HTL represents a viable option to produce high-quality fuels, especially for wet biomass.
- AtJ (Alcohol-to-Jet) fuel could also be available for medium-term use. However, there are considerable economic concerns: Ethanol (or other alcohols) represent commercial commodities that can already be sold at higher prices than jet fuel.
- Lipids are currently very expensive, thus affecting the economic viability of HEFA fuels.
- For long-term applications possibly more radical, disruptive technologies will reach commercial maturity.

Sierk de Jong

- Considers HEFA as the only viable option for short-term applications and mentions examples of continuous production of HEFA fuels (e.g. a new HEFA plant in California), although still no large volumes are produced (world production currently equals about 3 million t/y).
- As all presently operational HEFA plants are mainly producing renewable diesel (not jet fuel), utilization of renewable diesel as blend stock for jet fuel might prove another viable option for short-term implementation.
- Jet fuel production via Fischer-Tropsch route has not yet shown economic viability and business cases are not sufficiently convincing.
- For medium-term regional solutions should be considered taking into account region-specific situations and conditions (e.g. large-scale availability of low-cost sugar in Brazil (when produced sustainably) and forestry residues in Scandinavia and Canada).
- The liquefaction pathways yielding a low-oxygen biocrude (e.g. HTL and catalytic pyrolysis) seem the most promising option for medium term implementation.

- The business cases for ATJ and DSHC (direct sugar to hydrocarbons) are challenging as long as selling the intermediate products is more profitable than converting it to jet.
- There is no “silver bullet”, i.e. not a single technology will solve all problems and meet all needs and requirements. It is important to look at different options and focus on technologies that are “feedstock-agnostic”. Regional niches for cheap resources might favor different technologies for fuel production.
- It is important to consider the entire value chain when developing business cases.

Question a-3: Which role do potential sustainable availability of required feedstock and flexibility in terms of feedstock types and sources play in this respect?

Inmaculada Gomez

- Availability of feedstock and flexibility is very important. Therefore feedstock has to be thoroughly considered. If flexibility is lacking, entire value chains can fail if only a single player fails.

Question b-1: What are the current state of development and future perspectives of these technologies (i.e. special, but not exclusive, focus on hydrothermal liquefaction and pyrolysis)?

Question b-2: What are the technical bottlenecks? Can you specify key milestones/decision points for further development, e.g. in the form of a roadmap towards commercialization?

Patrick Biller

- Technological barriers can be overcome; major bottlenecks exist with respect to feedstock (availability, sustainability, price etc.).
- ***HTL (hydrothermal liquefaction)*** is technically feasible for medium-term commercial application, but more development is needed on the feedstock side. Further development should focus on decentralized facilities with a large central facility for upgrading.

John Holladay

- The main development aim addresses operational stability over a long period of time.
- ***Pyrolysis***: Typical bottlenecks are low yields and catalyst problems. Key challenge is the low quality (in terms of thermal and chemical stability, corrosive character, etc.) of pyrolysis oil that makes it difficult and expensive to process.
- Yields highly depend on catalyst performance: Catalyst improvements decreased price by approximately 90% (< 4.50 US$/gal).
- Quantity vs. quality: Absolute yields of bio-oil or bio-crude are not the only crucial parameter. Quality matters, because it determines the complexity and consequently the (economic as well as ecological) costs of the upgrading process. Improving the quality of the oil as intermediate product is crucial for the overall process performance.

David Chiaramonti

- Advantage should be taken from existing experience and "lessons learnt" from technologies which have already reached the deployment stage.
- Complementary processes should be integrated so that residues from one process function as feedstock for another. (Jet) fuel production should be based on separated feedstock streams instead of raw (and complex) biomass material.

Question c: What are the challenges and crucial steps with respect to ASTM certification for new or novel technologies on their way towards commercialization?

Inmaculada Gomez

- ASTM certification process is quite expensive with respect to time and efforts. There is currently a big gap between (the speed of) scientific development on one side and the time-consuming and slow testing procedure for ASTM certification.

Sierk de Jong

- Clustering of technology providers in joint 'Task Forces' at ASTM in order to reduce cost and time.
- ASTM represents a main bottleneck for commercialization.
- Only "big players" can afford to go through the certification process.

Plenary discussion

Participants of the workshop were invited to ask questions to the panelists and/or express their views with respect to the topics discussed.

Question: Potential of utilization of waste material as feedstock for liquefaction processes?

David Chiaramonti

- Prices of wastes will rise quickly as a consequence of newly generated demand, rendering profitability questionable.
- Breakthrough development of biochemical processes might offer viable options for waste-based fuel production processes.

John Holladay

- Simple (thus efficient with low associated costs) processes are needed to break up the biomass structure. Enzymatic processes usually prove too costly.
- Positive example: Diesel production from crude tall oil (waste stream of paper production) has successfully been developed and applied by UPM (Finland).

Question: Incentives for the development of technologies and deployment?

John Holladay

- The challenge is to achieve the right goal with these incentives.
- Incentive schemes should be technology-agnostic.

Sierk de Jong

- Incentives are very important for deployment. Examples are projects at the Airport of Oslo and Schiphol Airport.

Xavier Dommange

- Within incentive schemes the connection of different sectors is important. Incentive programs for aviation fuels should thus be coupled with incentives for road transport fuels.

Concluding panel discussion

Each panelist was invited to present a concluding statement with focus on the discussed perspectives of conversion technologies and the crucial challenges to be addressed towards commercialization.

Patrick Biller

- We are in need of a big push to get the technologies to the market; promising new projects and ideas are currently under development.

Inmaculada Gomez

- Conversion technologies should not be considered separately from feedstock. We need more combined (full value chain) efforts.
- Barriers associated with ASTM certification should be lowered.

Xavier Dommange

- Regional differences need to be more thoroughly considered.

Sierk de Jong

- Currently discussed and developed technologies differ in terms of performances, technical/feedstock requirements, potentials and drawbacks. Thus, geographically different niche-markets could be a good starting point.

John Holladay

- Simplicity of processes is mandatory with respect to economic viability. Costs need to be reduced.
- Technologies also need to be flexible in terms of required feedstock.

Annex 1 - Workshop Programme
Monday, 1 June 2015 (15:00-19:00)

14:30 *Registration*

15:00 **Welcome to the Workshop**

RAINER JANSSEN AND DOMINIK RUTZ, WIP RENEWABLE ENERGIES, GERMANY

15:10 **CORE-JETFUEL Activities and Results**

JOHANNES MICHEL, FNR, GERMANY

15:30 **Introduction to CORE-JetFuel Technology Assessment Methodology**

ARNE ROTH, BAUHAUS LUFTFAHRT, GERMANY

Innovative Value Chains for Alternative Aviation Fuels

15:40 **Alternative Fuels for Aviation – Status quo and Perspectives of Different Options**

FRANZISKA MÜLLER-LANGER, DBFZ, GERMANY

16:00 **Research on Hydrothermal Liquefaction for the Production of Aviation Fuels**

PATRICK BILLER, UNIVERSITY OF LEEDS, UK

16:20 **Milestones for Microalgae Aviation Fuels**

XAVIER DOMMANGE, AIRBUS GROUP INNOVATIONS, FRANCE

16:40 *Coffee Break*

17:00 **The BIOREFLY Project – Industrial Demonstration of Paraffinic Aviation Biofuels**

DAVID CHIARAMONTI, RENEWABLE ENERGY CONSORTIUM FOR R&D (RE-CORD), ITALY

17:20 **Jet Fuel Advances in Bio-oil and Alcohol Upgrading**

JOHN HOLLADAY, PACIFIC NORTHWEST NATIONAL LABORATORY, USA

17:40 **Panel Discussion on Technology Assessment**

MODERATION: ARNE ROTH, BAUHAUS LUFTFAHRT, GERMANY

PANELLISTS:

FRANZISKA MÜLLER-LANGER, DBFZ, GERMANY
DAVID CHIARAMONTI, RE-CORD, ITALY
XAVIER DOMMANGE, AIRBUS GROUP INNOVATIONS, FRANCE
PATRICK BILLER, UNIVERSITY OF LEEDS, UK
SIERK DE JONG, SKYNRG, NETHERLANDS
JOHN HOLLADAY, PACIFIC NORTHWEST NATIONAL LABORATORY, USA
INMACULADA GOMEZ, SENASA, SPAIN

18:50 **Summary**

DOMINIK RUTZ, WIP RENEWABLE ENERGIES, GERMANY

19:00 *End of the workshop*

Annex 2 – List of Workshop Participants – Part 1

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