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

WP3: International Expert and Stakeholder Exchange

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Johannes Michel
- Coordinator-
Fachagentur Nachwachsende Rohstoffe e.V. (FNR)
j.michel@fnr.de
Tel.: +49 (0) 3843 – 69 30 – 250
Fax: +49 (0) 3843 – 69 30 – 102

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

Deliverable 3.11
Report on International Cooperation Liaison
CAAFI-CORE-JetFuel Cooperation Workshop

SUBMITTED VERSION 1.0

Document authors and contributors: R. Janssen, D. Rutz, WIP Renewable Energies, J. Michel, FNR

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

PROJECT PARTNERS

FNR – Fachagentur Nachwachsende Rohstoffe e.V., Germany

BHL – Bauhaus Luftfahrt e.V., Germany

SENASA - Servicios y Estudios para la Navegación Aérea y la Seguridad Aeronáutica SA, Spain

IFPEN – IFP Energies Nouvelles, France

WIP- WIP Renewable Energies, Germany

AGI – Airbus Group Innovations

EXECUTIVE SUMMARY

On April 28th 2016, the CORE-JetFuel project jointly organized a Cooperation Workshop with the Commercial Aviation Alternative Fuels Initiative (CAAFI) in Alexandria, USA. The aim of this workshop was to bring together experts from the U.S. and Europe in the area of alternative aviation fuels in order to discuss policy options for the large-scale deployment of bio-jet fuels, promising production technologies and value chains as well as the impact of low oil prices on investments in alternative aviation fuels.

In addition, possibilities for the harmonization of sustainability requirements anchored in legal frameworks of the respective continents were sought and a potential coordination of a stakeholder strategy on alternative aviation fuels was discussed. Form the European perspective, focus was placed on learning from experiences with sustainable alternative jet fuels in the U.S.

Prior to the Cooperation Workshop on April 28th 2016, members of the European delegation were invited to join presentations of alternative fuels projects in the framework of the FAA Center of Excellence for alternative jet fuels and environment (ASCENT) Spring Meeting on April 27th 2016.

The main findings of the Cooperation Workshop included:

- In order to ensure long-term support programmes, initiatives on alternative aviation fuels need to be integrated in existing mechanisms (e.g. RFS in U.S., RED in EU)
- With respect to technology assessments, existing uncertainties need to be clearly indicated that arise from extrapolating R&D technology results towards global production potentials
- Level playing fields need to be established for road and aviation fuels, and for biofuels versus fossil fuels.
- In order to ensure long-term support programmes, initiatives on alternative aviation fuels need to be integrated in existing mechanisms (e.g. RFS in U.S., RED in EU)
- Complementary of support initiatives and programmes is of large importance, such as the joint initiatives by the Navy, Department of Energy (DOE) and Department of Agriculture (USDA) in the U.S..
- Stable policy frameworks are needed for the development of alternative fuels, both for road and aviation applications.

With this Cooperation Workshop, the CORE-JetFuel project successfully realized one of its major milestones, namely the stimulation of a vivid exchange of ideas between Europe and the United States in the field of alternative aviation fuels.

TABLE OF CONTENT

LIST OF FIGURES AND TABLES

Document Information

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LIST OF ABBREVIATIONS

C-JF	CORE-JetFuel - Coordinating research and innovation in the field of sustainable alternative fuels for aviation
CAAFI	Commercial Aviation Alternative Fuel Initiative
A4A	Airlines for America
ACARE	Advisory Council for Aviation Research and Innovation in Europe
Aireg	Aviation Initiative for Renewable Energy in Germany e.V.
ANL	Argonne National Laboratory
ASCENT	Aviation Sustainability Center
ASTM	American Society for Testing and Materials
AtJ	Alcohol-to-Jet
BtL	Biomass-to-Liquid
CapEx	Capital Expenditure
CCE	Camelina Company España
CO_2	Carbon Dioxide
DG	Directorate General
DOE	Department of Energy
DPA	Department of Agriculture
DPA	Defence Production Act
DSHC	Direct Sugar to Hydrocarbon
e.g.	for example
EC	European Commission
EIBI	European Industrial Bioenergy Initiative
EPA	Environmental Protection Agency
ETS	European Trading Scheme
FAA	Federal Aviation Administration
FQD	Fuel Quality Directive

FT	Fischer Tropsch
GHG	Greenhouse Gas
GMBM	Global Market-Based Measure
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
HDCJ	Hydroprocessed Depolymerized Cellulosic Jet
HDCJ	Hydroprocessed Depolymerized Cellulosic Jet
HEFA	Hydroprocessed Esters and Fatty Acids
i.e.	it est
ICAO	International Civil Aviation Organization
iLUC	Indirect Land Use Change
ISAFF	Italian Sustainable Aviation Fuel Forum
ITAKA	Initiative Towards sustAinable Kerosene for Aviation
LCA	Lifecycle Analysis
MCA	Multi-Criteria Approach
NISA	Nordic Initiative for Sustainable Aviation
NREL	National Renewable Energy Laboratory
OpEx	Operational Expanditure
PM	Particulate Matter
PNNL	Pacific Northwest National Laboratory
PtL	Power-to-Liquid
R&D	Research and Development
RED	Renewable Energy Directive
RFS	Renewable Fuel Standard
RSB	Roundtable on Sustainable Biomaterials
SAFUG	Sustainable Fuel Users Group
SAJF	Sustainable Alternative Jet Fuels
StL	Sun-to-Liquid
TRL	Technology Readiness Level

UCO	Used Cooking Oil
WtW	Well-to-Wake

CAAFI – CORE-JetFuel Cooperation Workshop

28 April 2016 in Alexandria, USA

on the occasion of the FAA (Federal Aviation Administration)
ASCENT SPRING Meeting on 25-29 April 2016

WORKSHOP SUMMARY

CORE-JetFuel is co-funded by the European Commission in the 7th Framework Programme (Project No. FP7-605716) – www.core-jetfuel.eu

1 Workshop Background

This workshop was 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 was to **facilitate discussion among experts from the U.S. 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
- Harmonization of sustainability requirements
- 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 were 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.

Workshop Organisation

Rainer Janssen, Dominik Rutz
WIP – Renewable Energies, Germany
Tel. +49 (0) 89 720 12743, Fax +49 (0) 89 720 12791
E-Mail: rainer.janssen@wip-munich.de, dominik.rutz@wip-munich.de

Johannes Michel
Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Germany
Tel.: +49 (0) 3843 6930 250, Fax: +49 (0) 3843 6930 102
E-Mail: j.michel@fnr.de

Steve Csonka
Executive Director, CAAFI
Tel. +1 513 800 7980
E-Mail: Csonka.CAAFI.ED@gmail.com

Workshop Summary

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

Workshop Presentations

Presentations are available at the website: http://www.core-jetfuel.eu/nav/events5.aspx

2 WORKSHOP SUMMARY

28 April 2016

2.1 Opening Session

The CAAFI - CORE-JetFuel Cooperation Workshop was opened by **Steve Csonka**, Executive Director of the U.S. Commercial Aviation Alternative Fuels Initiative (CAAFI) and **Rainer Janssen** and **Dominik Rutz**, WIP Renewable Energies, Germany. This workshop was jointly organised to facilitate discussion among experts from the U.S. and Europe in the area of alternative fuels for aviation.

The cooperation workshop was launched by a brief introduction to the aims and activities of the U.S. Commercial Aviation Alternative Fuels Initiative (CAAFI) by **Steve Csonka**. As Public-Private Partnership CAAFI is an aviation industry coalition established to facilitate and promote the introduction of alternative aviation fuel. The goal of CAAFI is the development of non-petroleum, drop-in, jet fuel production with the aim to achieve equivalent safety and performance, comparable cost and environmental improvements in order to contribute to security of energy supply for aviation. Focus is thereby placed on synthetic kerosene primarily from renewable sources. CAAFI is an initiative that enables its diverse stakeholders to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels.

The office of the CAAFI Executive Director is funded by the FAA (U.S. Federal Aviation Administration) within its activities to support the coordination of U.S. activities in the field of alternative jet fuels. CAAFI has more than 800 global sponsors and stakeholders from aircraft, engine and subsystem manufacturers, airlines and airports, academia and Government labs, Federal and State Government Offices, fuel producers and suppliers, as well as other supply chain partners.

CAAFI operates along four work teams on Research and Development (enabling multiple “drop-in” solutions), Certification and Qualification (fostering ASTM D7566 approval), Environmental issues (GHG emissions, LCA, sustainability), and Business issues (facilitating deployment and investments). Thereby, cooperative research, development and deployment initiatives are promoted along the full value chain including feedstock production and logistics, fuel conversion, testing and approval, full-scale production, as well as end use at airports and airlines.

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

- Develop and implement a strategy for sharing information, for coordinating initiatives, projects and results,
- Identify needs in research, standardisation, innovation and policy measures at European level,

- Evaluate the research and innovation “landscape” with collection of the lessons learned in order to support decision makers in setting priorities for the European funding strategy.

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. In order to evaluate the performance of the identified bio-jet production pathways, a multiple-criteria approach (MCA) is applied. This MCA makes up the three key (“high-level”) criteria of alternative aviation fuels, namely Suitability (e.g. “Drop-in” capability), Scalability (e.g. production potential), and Sustainability (e.g. GHG Emission reduction potential).

Finally, the following preliminary conclusions were presented by Mr. Michel:

Short-term application (2020)

- Availability limited by maturity of conversion technology
- HEFA from oils/fats, SIP from sugar (DSHC)

Medium-term application (2035)

- Maturing of pathways based on lignocellulosic feedstock (high “potential reward”: carbon footprint/production potential)
- Development of renewable non-biogenic options proceeds

Long-term application (2050)

- Large quantities needed with high “potential reward”
- Feedstock availability and specific environmental performance increasingly important
- (High risk)/high gain options

An overview of the U.S. status of alternative aviation fuels was presented by **Steve Csonka** from CAAFI. Achievements to date include the alignment of industry, proofs of technical viability and the identification of several versatile solutions. However, main remaining challenges today concern risk, affordability, financing, execution, feedstock availability as well as the further development of production processes.

Within the coming years first modest amounts of sustainable alternative jet fuels (SAJF) will be produced at AltAir Fuels facility (from March 2016) and three facilities (in 2018) receiving funding under the Defense Protection Act (DPA) Initiative. Under the DPA Initiative the Navy entered into an MOU (Memorandum of Understanding) with the Department of Energy (DOE) and the Department of Agriculture (USDA) to fund the commercialization of three fuel production facilities with a combined nameplate production level of 104 million gpy (395,000m^3/y or approximately 296 kt/y) biofuel. The agencies jointly funded the program at ~$510 million over 3 years.

Furthermore, an important means to reduce risk and facilitate investment security is the establishment of airline off-take agreements. Today, such agreements exist between United Airlines and AltAir Fuels (5 million gallons per year (gpy) from 2016), United and Fulcrum (90-180 million gpy over 10 years), Alaska Airlines and Hawai'I BioEnergy (supply from 2018), Cathay Pacific and Fulcrum (>465 million gallons over 10 years), Southwest/FedEx and Red Rock Biofuels (each 3 million gpy).

Sarted in March 2016, AltAir Fuels is the first dedicated U.S. (and world) production facility for HEFA-SPK fuels in Paramount, California with an initial biofuel capacity of 40 million gpy (152,000m^3/y or approximately 120 kt/y), with about 30% of the production corresponding to biojet fuel. The three current DPA recipients are Red Rock Biofuels and Fulcrum Bioenergy, (Gasification + FT synthesis) and Emerald Biofuels (HVO). Red Rock Biofuels receives a $70 million DPA Title III award for its $200 million refinery to produce 12 million gpy (45,600 m^3/y or approximately 34 kt/y) of renewable, liquid transportation fuels from 140,000 dry tons of woody biomass feedstock. Fulcrum Bioenergy is a DPA Phase 2 winner and receives a USDA Loan Guarantee for the construction of a production facility for 11 million gpy (41,800 m^3/y or approximately 31 kt/y) liquid fuels from 147,000 tons of post-recycled waste. Finally, Emerald Biofuels aims at a 88 million gpy (334,400 m^3/y or approximately 260 kt/y) biodiesel capacity from lipids and pursues a development programme to achieve a >500 million gpy production capacity portfolio.

In addition to these existing and planned production facilities CAAFI is promoting a large number of technology pathways currently in the ASTM certification pipeline (e.g. microbial conversion, hydrothermal oils, renewable diesel, refinery co-processing) aiming at improved SAJF affordability (reduced process costs, lower CapEx, OpEx) and increased (regional and global) feedstock availability.

In conclusion the U.S. programmatic goals and plans in the field of SAJF aim at establishing aviation as a first mover and dedicated long-term off-taker of SAJF (soon) produced at petroleum pricing parity. The FAA has set an ambitious aspirational goal of 1 billion gpy (3,8 million m^3/y or approximately 2850 kt/y) by 2018 and DLA acts as a regular off-taker for SAJF with the objective to significantly reduce technology and execution risk to unlock capital for the large-scale deployment of SAJF.

The status of alternative aviation fuels in Europe was presented by **Remy Denos**, DG ENERGY, European Commission. In his introduction Mr. Denos recalled the targets of the EU climate and energy policy, namely the binding targets for 2020: 20% GHG emission reduction (compared to 1990) and 6% GHG emission reduction in transport (compared to 2010), 20% share of RE in EU energy consumption and 10% RE share in transport, 20% improvements in energy efficiency; and the targets for 2030: 40% GHG emission reduction (compared to 1990, binding), 27% share of RE (binding at EU level only, no sub-target for transport), 27% improvements in energy efficiency.

Recently, the so-called "ILUC Directive" (Directive 2015/1513), amending the Fuel Quality Directive (98/70/EC) and the Renewable Energy Directive (2009/28/EC), was published including the following main issues:

- Renewable transport fuels of non-biological origin

- 1st generation biofuels capped to 7%
- Member States to report about Indirect Land Use Change
- Indicative target of 0.5% of advanced biofuels (advanced biofuels count double)
- Transposition deadline: 10/09/2017
- In the case of suppliers of biofuels for use in aviation, Member States may permit such suppliers to choose to become contributors to the reduction obligation provided that those biofuels comply with the sustainability criteria.
- Installation starting operation after 5 October 2015 shall produce fuels with at least 60% of GHG savings.

The EU Emission Trading Scheme (ETS) was initiated in 2005 with the aim to "cap and trade" GHG emissions. Since 2012 aviation is included in ETS (Directive 2003/87/EC). Due to the present low effectiveness of ETS in reducing GHG emissions, for the time beyond 2020 the overall number of emission allowances will decline at an annual rate of 2.2% from 2021 onwards, compared to 1.74% currently.

In summer 2016 the EC will propose legislation to achieve the greenhouse gas reduction target as well as a communication on decarbonisation of transport. By the end of 2016, the EC will propose a new Renewable Energy Package including a new policy for sustainable biomass and biofuels.

In 2012 biofuels consumption in the EU was 14.5 Mtoe (mainly biodiesel and bioethanol) which accounted for 5.3% of transport energy consumption. This total amount represents about 30% of the about 50 Mtoe final energy consumption of the air transport sector. Thereby, GHG emissions from the aviation sector (incl. international bunkers) represent 12.8% of transport GHG emissions or 2.5% of total emissions.

Past and on-going initiatives at EU level include coordination projects (BIOJETMAP, CORE-JetFuel and Forum AE), research projects (DREAM, Alfa-Bird, SWAFEA, Solar Jet) and demonstration projects (ITAKA, BIOREFLY, BFSJ). On policy level initiatives include EuroCAEP, ACARE WG3 and the European Advanced Biofuel Flight Path Initiative which is part of the European Industrial Bioenergy Initiative (EIBI) of the EU SET-Plan and specifies a production target of 2 million tons of biofuels blended with kerosene per year by 2020 (i.e. ~4% of current volumes). Until today, however, achievements towards this target are negligible.

In conclusion, for the "way forward" Mr. Denos stated the importance of further activities in the areas RTD, demonstration and scaling-up entire value chains. Additional production pathways for alternative aviation fuels need to be certified and sustainability criteria need to be harmonised at international level. Finally, with respect to economics market based measures are being discussed at ICAO. But in the current period of transition, smart solutions need to be found to fund extra costs of biofuels towards production volumes of >100 000 tons/y.

3 Discussion Panel I: Supply Chain Development and Deployment of Alternative Fuels

Moderation

- Nate Brown, FAA, USA
- Maria de la Rica Jimenez, SENASA, Spain

In his introductory presentation to Discussion Panel I **Nate Brown** from FAA highlighted the main support mechanisms and complementarity of programmes in the fields of public R&D investments, public development policies and coordinating initiatives in order to address barriers to alternative jet fuels in the U.S..

Public R&D investments

- Funding and/or cost sharing of technology R&D
- Testing and analysis
- Analytical tools, planning, studies

Public Deployment Policies

- Fiscal incentives (tax credits/rebates)
- Public financing (loans, loan guarantees, grants)
- Regulations (mandates, quotas)
- Government (& airline) procurement

Coordinating Initiatives

- Public Private partnerships (CAAFI, Farm to Fly 2.0)

The following main objectives for future development of alternative jet fuels in the U.S. are addressed by a variety of complementary initiatives and programmes:

Increase feedstock availability

- R&D on feedstock & cost (e.g. Agriculture, Energy grants)

Reduce fuel costs through R&D investment

- Improve conversion cost (e.g. Energy, DARPA grants)

Reduce risks of approval process

- R&D support for testing of fuels (e.g. FAA, Defense, NASA)

- Transparent process for certification/qualification

Reduce uncertainty on environment

- Improve quantification of benefits
- Work towards converging standards for crediting

Increase investment in production

- Reduce cost & risk of production of feedstock (e.g. Agriculture BCAP, crop insurance programs)
- Reduce cost to finance first of a kind plants (e.g. loan guarantees by Agriculture and Energy)
- Direct investment in fuel production (e.g. Navy, Energy, Agriculture, Defense Production Act)
- Provide fuel production incentives (e.g. the U.S. Environmental Protection Agency's Renewable Fuel Standard)
- Purchases and off-takes to create market (e.g. Department of Defense, Farm to Fleet and Airlines)

Establish supply chains

- Linking up stakeholders for supply (e.g. CAAFI & F2F2)

For the European side the introductory presentation to Discussion Panel I was held by **Maria de la Rica** from SENASA, Spain. In order to contribute to the objectives laid down in the 2020 European Energy and Climate Strategy, in 2011 the EU Advanced Biofuels Flightpath set the objective to achieve 2 million tons of sustainable biofuel per year by 2020. Thereby, focus was placed on the promotion and creation of efficient supply chains from supply (biomass cultivation and conversion) to demand (airlines and standards).

During past years a number of flights were performed using alternative aviation fuels, namely 1189 flights by Lufthansa connecting Frankfurt and Hamburg (July-December 2011) on HEFA jet, weekly Air France flights from Toulouse to Paris-Orly with 10% farnesane during 1 year starting in 2014 as well series of 20 and 80 flights by KLM in May 2014 and March 2016 on camelina/UCO HEFA jet (ITAKA project, also refer to ITAKA presentation by Inmaculada Gomez in Discussion Panel II section).

Projects at EU level for the development of supply chains for alternative aviation fuels include SOLAR-JET (2011-2015), ITAKA (2012-2016), BSFJ (2015-2019) and BIOREFLY (2015-2018). ITAKA aims to demonstrate the whole value chain to produce HEFA-SPK from Camelina oil and UCO at Neste Oil's refinery at Porvoo, Finland. The objective of BIOREFLY is to demonstrate the thermo-chemical conversion of lignin to jet fuel in an integrated industrial demo scale plant with a capacity of 2,000 ton/y. SOLAR-JET is a R&D project to

demonstrate at lab-scale a process that combines concentrated sunlight with CO_2 captured from air and H_2O to produce synthetic kerosene. Within the project BSFJ, Swedish Biofuels AB aim at the construction of a pre-commercial demonstration plant for the production of fully synthetic paraffinic jet fuel from wood and other biomass. Furthermore, the European Commission funds a number of coordination efforts such as the projects CORE-JetFuel. FORUM-AE, and BIOJETMAP.

In addition, the following national initiatives on alternative aviation fuels exist on Member State level: Aviation Initiative for Renewable Energy in Germany e.V. (AIREG), Nordic Initiative for Sustainable Aviation (NISA), Bioport Holland, Spanish Bioqueroseno initiative, Lab'Line for the Future in France and the Italian Sustainable Aviation Fuel Forum (ISAFF).

3.1 Plenary Discussion: Supply Chain Development and Deployment of Alternative Fuels

The following comments and statements were made by speakers and participants of the CAAFI - CORE-JetFuel Cooperation Workshop:

- There is interest in the U.S. for the fully synthetic paraffinic jet fuel to be produced by Swedish Biofuels AB. Joint testing of this fuel is performed in cooperation with the Swedish Air Force.
- The demonstration plant to be operated by Biochemtex Spa within the project BIOREFLY will be based on the up-scaling of a pilot plant with a lignin capacity of 2.5 kg/h for the production of aviation fuels currently in operation at the Biochemtex RTD facility Sharon Centre in the USA.
- In order to ensure long-term support programmes, initiatives on alternative aviation fuels need to be integrated in existing mechanisms (e.g. RFS in U.S., RED in EU)
- Complementary of support initiatives and programmes is of large importance, such as the joint initiatives by the Navy, Department of Energy (DOE) and Department of Agriculture (USDA) in the U.S..
- No specific single authority is governing programmes on alternative aviation fuels, but good working conditions exist between different authorities. Coordination support is provided by CAAFI.
- Customers and end users of alternative aviation fuels need to be closely involved in support programmes in order to ensure market demand.
- Very large scale public investment support (such as the 510 Million U.S.$ programme launched under the DPA Initiative) is required to significantly advance the deployment of alternative aviation fuels.
- With this support programme the U.S. aims at replicating the successful programmes for the promotion of ethanol and biodiesel.

- Stable policy frameworks are needed for the development of alternative fuels, both for road and aviation applications. Also in the U.S. uncertainty with respect to the policy timeframe exists, as the RFS/RIN system is put into question.
- Opposition against the RFS/RIN system is voiced by the petroleum industry in order to protect their economic interests.
- Competition exists between use of alternative fuels in road and aviation sectors.
- Care needs to be taken to ensure public support for alternative fuels. Public opinion is still influenced by early bad practices during the introduction of ethanol.
- Integrated systems for the production of food and fuels that create multiple income sources need to be promoted.
- Focus needs to be placed on agricultural and industry wastes.
- Within the future bioeconomy emphasis needs to be placed on higher value products due to biomass feedstock limitations.
- Information exchange on successful off-take agreements is needed between producers, airlines and the public.
- Key elements for off-take agreements include a certified and safe fuel and stable policy frameworks. Issues of cost-competitiveness depend on specific agreement.
- Conventional financing via commercial banks is only possible for proven technologies (i.e. after about 10 plants implemented). The production facility by AltAir Fuels is funded with venture capital.

4 Discussion Panel II: Promising production technologies and value chains

Moderation

- Zia Haq, U.S. Department of Energy (DOE), USA
- Alain Quignard, IFPEN, France, and Andreas Sizmann, Bauhaus Luftfahrt, Germany

In his introductory presentation to Discussion Panel II **Zia Haq** from the U.S. Department of Energy presented the following core focus areas of the DOE Bio-Energy Technology Office (BETO) in the fields of research, development, demonstration and market transformation:

Feedstock Supply & Logistics R&D

- Terrestrial
- Algae
- Product Logistics Pre-processing

Conversion R&D

- Biochemical
- Thermochemical
- Deconstruction
- Bio-intermediate
- Upgrading

Demonstration & Market Transformation

- Integrated Biorefineries
- Biofuels Distribution Infrastructure

Furthermore, BETO supports activities in the cross cutting areas of sustainability, strategic analysis and strategic communications.

DOE works to address risks and reduce costs across the supply chain with respect to the key challenges displayed in the table below.

Table 1: Key challenges of alternative aviation fuels along the value chain

Key Challenges			
Biomass	**Pretreatment**	**Conversion**	**Product**
• Reliable supply • Consistent quality • Affordable delivery	• Biomass feeding, sizing and moisture • Solids handling • Construction materials	• Products Yields • Construction materials • Catalysts • Fermentation organisms	• Separations • Catalytic upgrading • Recycle loops

In the framework of a recent biomass resource assessment, the baseline scenario found current combined resources from forests and agricultural lands of about 473 million dry tons at $60 per dry ton or less, whereas by 2030, estimated resources increase to nearly 1.1 billion dry tons. In the high-yield scenario, by 2030 total resource ranges from 1.4-1.6 billion dry tons annually.

Data on this biomass resource assessment is publicly available on the Bioenergy Knowledge Discovery Framework (https://www.bioenergykdf.net/).

Well-to-Wake (WtW) GHG emissions of alternative jet fuels were estimated using the **GREET™** (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model. It was found that GHG emission reductions of 30-60% and 60-90% are possible for oil

crop feedstock and lignocellulosic biomass, respectively (LUC-related emissions are not included in the model).

Highlights presented by Mr. Haq on lab and bench scale R&D activities include biofuels catalyst development at several national laboratories:

- PNNL (Pacific Northwest National Laboratory) - Alcohol to Jet
- NREL (National Renewable Energy Laboratory) – DME to branched paraffins
- ORNL (Oak Ridge National Laboratory) – dilute Alcohol to Jet
- ANL (Argonne National Laboratory – Catalyst characterization

Cooperation within industrial partnerships exists with the companies Vertimass, Virent, Lanzatech, and Kiverdi as well as with the three beneficiaries of the Defense Production Act (DPA) Initiative, namely Emerald Biofuels, Fulcrum Bioenergy, and Red Rock Biofuels (reported in the presentation by Steve Csonka).

For the European side the introductory presentation to Discussion Panel II was held by **Andreas Sizmann**, Bauhaus Luftfahrt and **Alain Quignard**, IFPEN.

The objectives of the research analysis performed within CORE-JetFuel include technology assessments of the state-of-the-art and potentials of technology pathways for the production of alternative aviation fuels with respect to environmental, economic and technical performance parameters as well as a portfolio assessment on the impact and balance of the existing R&D portfolio at European level.

The technology assessment of alternative fuel technologies was guided by the following relevant questions and followed a multi-criteria approach with criteria and metrics as displayed in the table below:

- How much can we make?
- What is the potential environmental impact?
- How much would it cost?
- Drop-in capable or not?
- What is the current state of development (maturity)?

Table 2: CORE-JetFuel Multi-Criteria Approach

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 [%]
***European* substitution potential**	Production potential relative to demand in 2050	σ [%]
Specific GHG emissions reduction	Specific lifecycle GHG emissions relative to conventional jet	ε [%]

The following graph shows an evaluation of **risk and potential reward** for several technology pathways for the production of alternative aviation fuels. Thereby, risk in technology development is related (but not identical) to Technology Readiness Level (TRL) (x-axis) whereas an identified potential reward is given by the potential impact on global GHG emission reduction (calculated as product of specific emission reduction and global substitution potential) (y-axis).

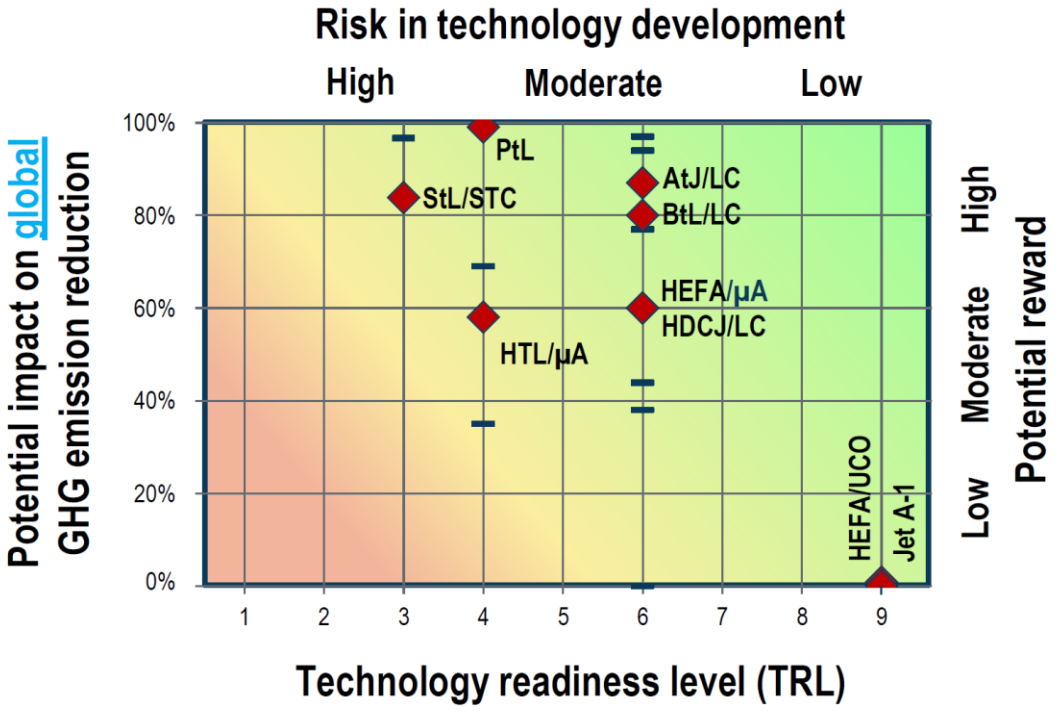

Figure 1: Risk and potential reward of developing selected production pathways

The HEFA/UCO (Hydroprocessed Esters and Farry Acids / Used Cooking Oils) pathway is a mature technology that shows an excellent environmental performance (i.e. high specific emission reduction), however the availability of feedstock is limited. Several technologies such as AtJ/LC (Alcohol to Jet), BtL/LC (Biomass to Liquid), HEFA/µA (microalagae), HDCJ/LC (Hydroprocessed Depolymerized Cellulosic Jet) are currently at TRL 6. Whereas AtJ/LC and BtL/LC pathways show a rather large global substitution potential, significant uncertainties exist today with respect to the performance and potential of algae based fuels (HEFA/µA). Power-to-Liquid (PtL) technologies are at lower TRL of about 4, but show a very large global substitution potential.

Overall, the following conclusions and recommendations from the CORE-JetFuel research analysis can be summarised.

- Most relevant performance indicators
    - GHG reduction potential: Product of carbon intensity and production potential
    - Costs of production as metric for potential economic competitiveness
    - Technical maturity as proxy for risk of development
- Balance of effort/funding dedicated to basic science and technology development
    - There is need for both technology development and basic science
    - Main objectives are: Balance in funding for basic science and technology development; Linking of basic science with technological innovation
- Overall portfolio analysis shows a 20/80 distribution between knowledge creation and product-oriented research
- Balance of risk and potential reward
    - Identify potential rewards for European energy supply security, competitive industries and socio-economic benefits
    - Identify high-reward options with balanced risk in the portfolio

Highest potential for European production and impact on GHG reduction: Lignocellulosic feedstock and renewable non-biogenic options (PtL, StL)Furthermore, results of the EU project ITAKA (Initiative Towards sustAinable Kerosene for Aviation) was presented by **Inmaculada Gomez** from SENASA, Spain. With respect to feedstock production, four camelina plantations are established in Spain and one plantation in Romania. New camelina varieties with increased oil content have been adapted for Europe and optimized camelina growing protocols have been developed.

On conversion technology, improved refining facilities are achieved which are better adapted to biojet requirements and improved protocols for in house quality testing have been elaborated. Engine and fuel systems testing have been performed including several flights operated by KLM, showing no detrimental effects on operation, as well as similar or slightly better fuel consumption properties. GHG savings estimated for the full value chain are about 60% (with low ILUC risks for plantations on fallow land), and RSB (Roundtable on

Sustainable Biomaterials) certification was achieved for the camelina plantations established by Camelina Company España (CCE).

The ITAKA project will organise its final workshop on 13-14 September 2016 in Madrid. Further information on the project is available at www.itaka-project.eu.

4.1 Plenary Discussion: Promising production technologies and value chains

The following comments and statements were made by speakers and participants of the CAAFI - CORE-JetFuel Cooperation Workshop:

- With respect to technology assessments, existing uncertainties need to be clearly indicated that arise from extrapolating R&D technology results towards global production potentials.
- The criteria “TRL” is not suitable to represent market risks, i.e. the opportunity to make profit and compete in global markets.
- Assessments of potentials need to address regional (and local) feedstock opportunities and the corresponding value chains.
- Studies are needed to investigate societal benefits (e.g. on net employment and GDP impacts) beyond classical business models.
- Technology assessments need to also include potential co-products and their markets. Markets for fuels and chemicals/products have different scales which may lead to demand limitations.

5 Discussion Panel III: Sustainability

Moderation

- Nancy Young, Airlines for America (A4A), USA
- Johannes Michel, FNR, Germany

An overview of the U.S. perspective on sustainability of alternative (aviation) fuels was presented by **Nancy Young** from Airlines for America (A4A). The U.S. overall objectives for alternative fuel deployment comprise energy security/supply reliability, replacement of petroleum, and environmental benefits. The latter includes potential life cycle GHG emissions improvements, the potential to reduce emissions with air quality impact (special focus on particulate matter (PM)), and the avoidance of other environmental problems such as water use, land use, and food-basket competition.

The FAA aspirational goal of "carbon neutral growth by 2020 compared to 2005" is fully in line with the aggressive CO_2 emission targets by the global aviation industry, leading towards 50% reduction in 2050 relative to 2005 levels.

Within regulatory sustainability requirements for alternative aviation fuels in the U.S., the only mandatory requirement is that the fuels be produced and deployed consistent with Federal & State environmental requirements (e.g., the feedstock producers, transporters, facility processing the feedstocks into fuels, etc. must meet Clean Air Act, Clean Water Act, waste management, etc. requirements). The following requirements exist for alternative jet fuels if the producer seeks to qualify it under the Renewable Fuel Standard (RFS 2):

- Demonstrated lifecycle GHG reduction compared to 2005 petroleum baseline (20% (Renewable Fuel), 50% (Advanced Biofuel), or 60% (Cellulosic), Indirect Land Use Change (ILUC) included)
- Cropland must have been cleared prior to December 19, 2007
- Feedstocks/pathways for alternative jet fuel must be approved by EPA after LCA analysis

Some U.S. alternative jet fuel producers and purchasers have also opted to meet voluntary sustainability criteria, such as:

A4A Commitment

""We seek alternative fuel sources having a reduced emissions profile relative to traditional fuels. We encourage all potential suppliers to work directly through CAAFI to ensure that their alternative jet fuel will meet accepted criteria to be more environmentally friendly than traditional jet fuel, in particular resulting in a reduced emissions profile on a lifecycle basis, without compromising critical uses of relevant feedstocks.""

(SAFUG) Sustainability Pledge by members of the Sustainable Fuel Users Group

In conclusion, Mrs. Young underlined aviation's unique need for acceptance of GHG LCA & relevant sustainability criteria across borders. Opportunities in this respect are provided by the GHG LCA methodology currently developed under ICAO for purposes of the Global Market-Based Measure (GMBM), and the ICAO initiative on potential sustainability criteria beyond GHG LCA criteria. CAAFI members are actively participating in this ICAO processes.

An introduction to the European perspective on sustainability of alternative (aviation) fuels was presented by **Horst Fehrenbach** from IFEU, Germany. The European regulation on biofuels consists of the following main Directives:

Renewable Energy Directive (RED) 2009/28/EC

"Each Member State shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10 % of the final consumption of energy in transport in that Member State." (Article 3 (4))

Fuel Quality Directive (FQD) 98/70/EC amended by 2009/30/EC

"Member States shall require suppliers to reduce GHG emissions from use of transport fuel by 6% in 2020 compared to baseline scenario" (Article 7a)

Both amended by Directive 2015/1513 (the so-called ILUC Directive)

Biofuels eligible for the RED 10% quota and for the FQD 6% target need to fulfil following sustainability criteria:

- Biofuels shall not be made from raw material obtained from land (status after January 2008)
    - with high biodiversity value (Primary forests, areas designated for protection, highly biodiverse grassland)
    - and with high carbon stock (forested areas, wetlands, peatlands)
- Raw materials cultivated in the EU must be in accordance with the minimum requirements for good agricultural and environmental condition
- GHG emission saving from the use of biofuels shall be at least: 35% (currently), 50% in 2017 and 60% for biofuels and produced in installations starting operation after 5 October 2015.

Rules for GHG emission calculation include the use of default values (as indicated in the annex of the directives), own calculation of actual values, or a combination of partial default values and own calculations.

The following measures to address Indirect Land Use Change (ILUC) challenges are indicated in the ILUC Directive:

- National reporting on GHG emission savings shall include the ILUC emissions
- Biofuels from oil crops, sugar crops as well as cereals and starch-rich crops shall contribute no more than 7 % in 2020 (cap!)

- Advanced biofuels (from non-land-using feedstock) should aim at 0.5% in 2020.

Furthermore, the EU strategy to overcome the ILUC issue includes the support by double-counting of advanced biofuels made from:

- Algae, bacteria
- Diverse sorts of bio-waste, organic waste etc.
- Diverse sorts of residues from agriculture or forestry (i.e. non-food (ligno-)cellulosic material)
- Diverse sorts of agricultural residues
- Used cooking oil and animal fats
- Renewable liquid and gaseous transport fuels of non-biological origin (e.g. Power-to-Liquid (PtL))

With respect to verification of compliance with the sustainability criteria, certification of complete chain of custody is necessary. The Member States shall require economic operators to show that the sustainability criteria have been fulfilled:

- by every consignment
- by applying mass balance systems,
- performed by recognized voluntary national or international schemes

In conclusion, Mr. Fehrenbach stated that EU policymakers have shown their readiness to adapt the sustainability requirements according to the scientific discourse. However, the discussion and implementation of sustainability requirements has not come to an end.

It will advance to find agreements on globally harmonized principles and compatible schemes and transfer the lessons learned to any other „bio-related“ sector, any fuel, bio-based materials, food and feed. Only this will solve the ILUC problem, the risk of leakage, and provide a level-playing ground.

5.1 Plenary Discussion: Sustainability

The following comments and statements were made by speakers and participants of the CAAFI - CORE-JetFuel Cooperation Workshop:

- GHG emission thresholds exist in both USA (RFS2) and EU (RED).
- ICAO Global Market-Based Measure (GMBM) provides the opportunity of moving towards global harmonisation of sustainability criteria.
- Setting GHG emission thresholds leads to risk mitigation with respect to climate impacts of alternative fuels.
- Monetary benefits should be granted for (improved) GHG emission savings.

- Pathways with better performance should be rewarded.
- Legislation in Germany has moved from (mandatory) volume quota to GHG emission reduction target in 2015 which acts as market incentive for biofuels with low GHG emissions.

6 Discussion Panel IV: Stakeholder initiatives for alternative aviation fuels – Progress and perspectives

Moderation

- Steve Csonka, CAAFI, USA
- Maria de la Rica Jimenez, SENASA, Spain and Rainer Janssen, WIP, Germany

Plenary Discussion

In the concluding discussion session the following comments and statements were made by speakers and participants of the CAAFI - CORE-JetFuel Cooperation Workshop:

- Future developments of alternative aviation fuels should focus on:
  - No or low cost feedstock
  - Conversion Technologies based on well-established pathways in order to reduce costs and to optimize final fuel yield and potential coproducts
  - Complementary incentives on State and Federal level
- Within KLM's corporate programme (towards "greening" of transport) the additional expenses for alternative fuels are shared between all stakeholders of the value chain (including customers).
- Airlines are not in favour of taxing aviation fuels.
- Short-term challenges towards carbon-neutral growth include fuel price, environmental issues and incentive based programmes.

- Policies are important to get initial production of alternative aviation fuels running.
- Level playing fields need to be established for road and aviation fuels, and for biofuels versus fossil fuels.
- Definition of “sustainable fuels” by type is problematic. Focus should be placed on performance rather than feedstock.
- Location matters for the establishment of full sustainable value chains.
- Co-products may provide opportunities to improve business cases.
- Focus needs to be on re-placing the full barrel of oil within biorefinery concepts. Kerosene is only one product of existing oil refineries.
- The role of Government is to reduce the risk for deployment of production facilities, including political, technological and business risks.
- Risk reduction serves to lower the risk premium for financing. Further support is needed to cover the high CapEx requirements.
- Then, existing biorefineries will evolve over time addressing a variety of markets.
- Increased cooperation between the U.S. and Europe in the field of ASTM certification of alternative aviation fuel pathways is needed.
- Until today, most burdens have been taken by the U.S.. For the AtJ pathway, all testing has been done by U.S. Navy, Army and airports.
- Stronger involvement and financial support by European stakeholders (e.g. for fuels testing) is needed as 50% of OEMs originate from Europe and certified pathways can be used by producers globally.
- Costs for ASTM certification is in the range of 8-12 million $ per pathway (including the cost of fuel, but excluding the investment costs for demonstration plants (which is approximately at least one order of magnitude higher or even more).
- There is a need to convince industry and policymakers to explore new pathways for alternative aviation fuels. Priority should be given to aviation fuels over road fuels due to limited alternatives in the sector.

7 Workshop Statements

The main aim of this workshop jointly organised by **CAAFI** and the EU project **CORE-JetFuel** was to **facilitate discussion among experts from the U.S. and Europe in the area of alternative fuels for aviation**. The following main statements were made during workshop discussion panels.

Supply chain development and deployment of alternative fuels

- In order to ensure long-term support programmes, initiatives on alternative aviation fuels need to be integrated in existing mechanisms (e.g. RFS in U.S., RED in EU)
- Complementary of support initiatives and programmes is of large importance, such as the joint initiatives by the Navy, Department of Energy (DOE) and Department of Agriculture (USDA) in the U.S..
- Customers and end users of alternative aviation fuels need to be closely involved in support programmes in order to ensure market demand.
- Very large scale public investment support (such as the 510 Million U.S.$ programme launched under the DPA Initiative) is required to significantly advance the deployment of alternative aviation fuels.
- Stable policy frameworks are needed for the development of alternative fuels, both for road and aviation applications.
- Care needs to be taken to ensure public support for alternative fuels. Public opinion is still influenced by early bad practices during the introduction of ethanol.
- Information exchange on successful off-take agreements is needed between producers, airlines and the public.
- Key elements for off-take agreements include a certified and safe fuel and stable policy frameworks. Issues of cost-competitiveness depend on specific agreement.

Assessment of production technologies

- With respect to technology assessments, existing uncertainties need to be clearly indicated that arise from extrapolating R&D technology results towards global production potentials.
- The criteria “TRL” is not suitable to represent market risks, i.e. the opportunity to make profit and compete in global markets.

- Assessments of potentials need to address regional (an local) feedstock opportunities and the corresponding value chains.

- Technology assessments need to also include potential co-products and their markets. Markets for fuels and chemicals/products have different scales which may lead to demand limitations.

Sustainability

- GHG emission thresholds exist in both USA (RFS2) and EU (RED).

- ICAO Global Market-Based Mechanism (GMBM) provides the opportunity of moving towards global harmonisation of sustainability criteria.

- Monetary benefits should be granted for (improved) GHG emission savings.

- Pathways with better performance should be rewarded.

Progress and perspectives

- Future developments of alternative aviation fuels should focus on:
    - No or low cost feedstock
    - Conversion Technologies based on well-established pathways in order to reduce costs and to optimize final fuel yield and potential coproducts, and
    - Complementary incentives on State and Federal level

- Policies are important to get initial production of alternative aviation fuels running.

- Level playing fields need to be established for road and aviation fuels, and for biofuels versus fossil fuels.

- Definition of “sustainable fuels” by type is problematic. Focus should be placed on performance rather than feedstock.

- Focus needs to be on re-placing the full barrel of oil within biorefinery concepts. Kerosene is only one product of existing oil refineries.

- The role of Government is to reduce the risk for deployment of production facilities, including political, technological and business risks.

- Increased cooperation between the U.S. and Europe in the field of ASTM certification of alternative aviation fuel pathways is needed.

- Stronger involvement and financial support by European stakeholders (e.g. for fuels testing) is needed as 50% of OEMs originate from Europe and certified pathways can be used by producers globally.

- There is a need to convince industry and policymakers to explore new pathways for alternative aviation fuels. Priority should be given to aviation fuels over road fuels due to limited alternatives in the sector.

8 Annex 1 - Workshop Agenda

Workshop Agenda

Thursday, 28 April 2016 (09:00-16:30)

09:00 **Welcome to the Workshop**

STEVE CSONKA, CAAFI, USA

RAINER JANSSEN AND DOMINIK RUTZ, WIP RENEWABLE ENERGIES, GERMANY

09:10 **Introduction to CAAFI**

STEVE CSONKA, FAA, USA

09:30 **INTRODUCTION TO CORE-JETFUEL**

JOHANNES MICHEL, FNR, GERMANY

09:50 **Alternative Aviation Fuels – Status in the U.S.**

STEVE CSONKA, CAAFI, USA

10:20 **Alternative Aviation Fuels – Status in Europe**

REMY DENOS, EUROPEAN COMMISSION, DG ENERGY

10:50 *Coffee break*

11:20 - 12:20 **Discussion Panel I: Supply Chain Development and Deployment of Alternative Fuels**

11:20 **Introductory presentation U.S.**

NATE BROWN, FAA, USA

11:30 **Introductory presentation EU**

MARIA DE LA RICA JIMÉNEZ, SENASA, SPAIN

11:40 **Discussion Panel I**

MODERATION: NATE BROWN, FAA AND MARIA DE LA RICA JIMÉNEZ, SENASA

PARTICIPANTS:

- ALL WORKSHOP PARTICIPANTS

12:20 – 13:50 **Lunch break**

13:50 – 14:40 **Discussion Panel II: Promising production technologies and value chains**

13:50 **Introductory presentation U.S.**

ZIA HAQ, U.S. DEPARTMENT OF ENERGY, USA

14:00 **Introductory presentation EU**

ALAIN QUIGNARD, IFPEN, FRANCE

14:10 **Brief Introductory to the EU Project ITAKA**

INMACULADA GOMEZ JIMENEZ, SENASA, SPAIN

14:15 **Discussion Panel II**

MODERATION: ZIA HAQ, U.S. DOE AND ALAIN QUIGNARD, IFPEN / ANDREAS SIZMANN, BAUHAUS LUFTFAHRT

PARTICIPANTS:

- ALL WORKSHOP PARTICIPANTS

14:40 – 15:30 **Discussion Panel III: Sustainability**

14:40 **Introductory presentation U.S.**

NANCY YOUNG, AIRLINES FOR AMERICA (A4A), USA

14:50 **Introductory presentation EU**

HORST FEHRENBACH, IFEU, GERMANY

15:00 **Discussion Panel III**

MODERATION: NANCY YOUNG, A4A, USA AND JOHANNES MICHEL, FNR, GERMANY

PARTICIPANTS:

- ALL WORKSHOP PARTICIPANTS

15:30 *Coffee break*

16:00 – 16:30 **Discussion Panel IV: Stakeholder initiatives for alternative aviation fuels – Progress and perspectives**

16:00 **Discussion Panel IV**

MODERATION: STEVE CSONKA, CAAFI AND MARIA DE LA RICA JIMÉNEZ, SENASA / RAINER JANSSEN, WIP RENEWABLE ENERGIES

PARTICIPANTS:

- ALL WORKSHOP PARTICIPANTS

16:30 **Summary**

9 Annex 2 – Brief description of projects and initiatives

The **CORE-JetFuel project** supports the European Commission in its analysis and evaluation of research and innovation projects in the field of sustainable alternative fuels for aviation. It links initiatives and projects at the EU and Member State level, serving as a focal point in this area to all public and private stakeholders.

CORE-JetFuel addresses competent authorities, research institutions, feedstock and fuel producers, distributors, aircraft and engine manufactures, airlines and NGOs. The project is aimed to identify needs in research, standardization, innovation, deployment, and policy measures at European level and to set up a European network of excellence for alternative fuels in aviation to bring together technical expertise and provide an integrated approach to alternative aviation fuels.

For more information, please visit: **www.core-jetfuel.eu**

The **Commercial Aviation Alternative Fuels Initiative (CAAFI)** seeks to enhance energy security and environmental sustainability for aviation through alternative jet fuels. CAAFI is a coalition that focuses the efforts of commercial aviation to engage the emerging alternative fuels industry. It enables its diverse participants - representing all the leading stakeholders in the field of aviation - to build relationships, share and collect data, identify resources, and direct research, development and deployment of alternative jet fuels.

For more information, please visit: **www.caafi.org**

Annex 3 – List of Workshop Participants

Name	Organisation	Country	Email
Johannes Michel	FNR	Germany	J.Michel@fnr.de
Rainer Janssen	WIP – Renewable Energies	Germany	rainer.janssen@wip-munich.de
Dominik Rutz	WIP – Renewable Energies	Germany	dominik.rutz@wip-munich.de
Maria de la Rica Jiménez	SENASA	Spain	mmrica@senasa.es
Inmaculada Gomez Jimenez	SENASA	Spain	igomez@senasa.es
Alain Quignard	IFPEN	France	alain.quignard@ifp.fr
Andreas Sizmann	Bauhaus Luftfahrt	Germany	Andreas.Sizmann@bauhaus-luftfahrt.net
Horst Fehrenbach	IFEU	Germany	horst.fehrenbach@ifeu.de
David Chiaramonti	University of Florence	Italy	david.chiaramonti@unifi.it
Franziska Mueller-Langer	DBFZ	Germany	Franziska.Mueller-Langer@dbfz.de
Remy Denos	European Commission – DG ENERGY	Belgium	Remy.DENOS@ec.europa.eu
Steve Csonka	CAAFI	USA	csonka.caafi.ed@gmail.com
Zia Haq	Department of Energy	USA	Zia.Haq@ee.doe.gov
Nate Brown	FAA	USA	Nathan.Brown@faa.gov
Mark Rumizen	FAA	USA	Mark.Rumizen@faa.gov
Mohan Gupta	FAA	USA	Mohan.l.gupta@faa.gov
Dan Williams	FAA	USA	Daniel.williams@faa.gov
Aniel Jardines	FAA	USA	Aniel.Jardines@faa.gov
Peter Herzig	DOT/Volpe	USA	Peter.Herzig@dot.gov
Kristin Lewis	DOT/Volpe	USA	Kristin.Lewis@dot.gov
Robert Malina	MIT	USA	rmalina@MIT.EDU
Chris Tindal	Department of the Navy	USA	chris.tindal@navy.mil
Bret Strogen	Department of Defence	USA	bret.m.strogen.ctr@mail.mil

Name	Organisation	Country	Email
Nancy Young	Airlines for America	USA	nyoung@airlines.org
Rob Myrben	Airlines for America	USA	rmyrben@airlines.org
Ralph Cavalieri	Washington State University	USA	cavalieri@wsu.edu
Mike Wolcott	Washington State University	USA	Wolcott@wsu.edu
Mike Gaffney	Washington State University	USA	mgaffney@wsu.edu
Scott Turn	University of Hawaii	USA	sturn@hawaii.edu
Trevor Morgan	University of Hawaii	USA	tmorgan@hawaii.edu
Steve Baughcum	Boeing	USA	
Michael Lakeman	Boeing	USA	michael.b.lakeman@boeing.com
Bruno Miller	Fulcrum	USA	bmiller@fulcrumbioenergy.com
Charles Murphy	Metron	USA	Charles.murphy@metronaviation.com
Ted MacDonald	Transport Canada	Canada	ted.mcdonald@tc.gc.ca
Med Colket	UTRC	USA	med@colket.org
Caroline Clifford	Pennsylvania State University	USA	
Katherine Zipp	Pennsylvania State University	USA	kyz1@psu.edu
Sasha Zaporozhets	Ukraine National Aviation University	Ukraine	zap@nau.edu.ua
Joelle Simonpietri	University of Hawaii	USA	joelle@arl.hawaii.edu
Olivier Penanhoat	SNECMA	France	olivier.penanhoat@snecma.fr