2 million tons per year:

A performing biofuels supply chain for EU aviation

August 2013 Update

<u>NOTE</u>
It is understood that in the context of this text the term "biofuel(s) use in aviation" categorically implies *"sustainably produced biofuel(s)"* according to the EU legislation.

August 2013 Update : Revision of the version initially published June 2011

The original 2011 technical paper was drafted by an editorial team from the European Commission, the biofuel producers and the aviation sector. The editorial team consisted of:

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Written contributions to the update were received from:

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The key finding of the original technical paper were presented to the stakeholders during a Workshop "*Achieving 2 million tons of biofuels use in aviation by 2020*" held in Brussels on 18 May 2011 (for the presentations and key points from the discussions please see:
http://ec.europa.eu/energy/technology/events/2011_05_18_biofuels_in_aviation_en.htm)

The Commission asked the stakeholder to provide comments, recommendations and suggestions on the technical paper. The technical paper then received input from some of the stakeholders and these where incorporated wherever appropriate. However, this technical paper is a living document and interested stakeholders may comment on it since it will be updated periodically. Those who wish to provide any input to this technical paper are kindly requested to forward their contributions to Mr. Kyriakos Maniatis at the following email: Kyriakos.Maniatis@ec.europa.eu quoting "Comments in Aviation Biofuel Flightpath".

The views and opinions expressed in this position paper cannot be held to reflect views of the European Commission or any of its departments.

2 million tons per year: A performing biofuels supply chain for EU aviation

PREAMBLE

The Biofuel FlightPath Initiative was introduced on the 24th of June 2011, at the 49th International Paris Air Show Le Bourget. The European Commission alongside with Airbus, Air-France-KLM, British Airways, Lufthansa and biofuel producers Chemtex Italia, Neste Oil, Biomass Technology Group, UOP and UPM are targeting two million tonnes annual production of fuel derived from renewable sources by 2020.

This initiative aims to achieve 2 million tons of sustainable biofuels to be used in aviation by 2020. In the EU policy framework it falls under the EU Strategic Energy Technology Plan.

For this purpose, a number of critical issues are identified and actions are proposed to address them (i.e. type of biofuel plants that need to be built, constructing a reliable financial mechanism etc), which are considered necessary in establishing a performing biofuels supply chain for the EU aviation.

This Implementation Plan and its accompanying FlightPath present the views of the industrial stakeholders and should be considered as a firm proposal from them on the actions to be carried out, and as a basis for further discussion with regard to the modalities proposed.

The objective of this position paper is to set out milestones to facilitate the deployment of sustainably produced advanced biofuels for the EU aviation sector that can be blended with kerosene and achieve a minimum annual replacement of 2 million tons fossil kerosene by 2020.

The Biofuels FlightPath is managed by its Core Team which consists of representatives from Airbus, Air France - KLM, British Airways and Lufthansa from the aviation side and BTG, Chemtex Italia, Neste, UOP and UPM on the biofuel producers side and is being implemented by a series of workshops addressing all key issues related to biofuels use in aviation. By June 2013 8 workshops have been organised byt the Core Team of the FlightPath. Information on these workshops can be found at:
http://ec.europa.eu/energy/renewables/biofuels/flight_path_en.htm**.**

A POSSIBLE FLIGHTPATH

To ensure the market uptake of bio kerosene in Europe, a target of 2 million tons per year of bio kerosene was established.

To achieve this 2 million tons biofuel penetration in the aviation fuels sector by 2020 the construction of the plants has to start soon. The deployment of the biofuels is foreseen in two steps; first the starting of operation of the first of its kind dedicated plants by 2015 and then a steady increase in supply chains to bring more bio kerosene to the market.

Nevertheless sustainable bio kerosene comes currently with significant cost penalty for the airlines. Besides the estimated € 3 billion investment in technologies and production facilities to enable a constant production flow of bio kerosene, mechanisms are also needed to bridge the cost penalty which is currently attached to bio kerosene. This penalty, currently calculated at € 3 billion for 2 million tonnes[1] (ca. 120 Eurocents per liter), reduces the potential market uptake.

This delicate balance between creating an international leading position in the development, substantial deployment of bio kerosene and the competitive position of European aviation requires a comprehensive approach taking the entire supply chain in consideration, from sustainable and affordable feedstock up to integration into the regular supply systems into the aircraft.

To address the users issue and facilitate a possible flight path, the following activities must be conducted, which require a substantial investment, in resources, time and cash:

- Policymakers:
  - Ensure availability of an appropriate set of supporting policies, including stable sustainability criteria.
  - Availability of a mix of financial support mechanisms for research, demonstration and commercial application for second generation biofuels
  - Safeguard an international level playing field.

- Bio kerosene supply chains stakeholders:
  - Ensure a clear understanding and use of effective financial mechanisms to provide confidence to the technology developers and investors for constructing the first-of-a-kind plants.
  - Development of quality standards and certified use of biofuels.
  - Ensure sufficient supply of sustainably produced feedstock
  - Develop mechanisms to create a real market for aviation biofuels through the implementation of the appropriate set of policies and specific financial support instruments for bio kerosene (e.g. market based measures) which take into account the international level playing field of aviation.

- Aviation stakeholders:

[1] Based on an existing additional premium of € 1.500 per ton on top of the fossil fuel price

- o Ensure an operational off-take agreement with Bio kerosene supply chains stakeholders.
- o Enable the validation of biofuels with on flight testing.
- o Facilitate and promote the policy dialogue with EU national government, European Parliament and European Commission.

Assuming the above activities are successfully and timely completed, the production facilities deployment roadmap supporting the possible flightpath (described in detail in Section B) is summarised below with the investments/costs expected:

2014: Implementation plan validated

2016: 300.000 tons of biofuel produced

- Commissioning 3 new plants
- € 1.300.000.000 for capital investment and production
- Routine use of bio kerosene on commercial flights

2018: 800.000 tons of biofuel produced

- Commissioning 4 new plants
- € 1.700.000.000 for capital investment and production

2020: 2.000.000 tons of biofuels produced deployed in the aviation market from 9 plants in operation

A. BACKGROUND, SCOPE & OBJECTIVES

Bioenergy will play a key role in the EU long term energy strategy for all applications and especially the transport sector, with biofuels contributing to 9.5 % of energy demand in transport in 2020[2]. The supply of feedstocks and the biofuel conversion technologies which are currently deployed already provide a significant contribution, but diversification of feedstocks and advanced technology will be necessary for further development. Especially for the aviation sector advanced conversion technologies need to be deployed for converting sustainably produced biomass feedstocks to biofuels that are fit for purpose by the aviation sector.

The EU Aviation Sector

Aviation is one of the strongest growing transport sectors. In the period up to 2050, worldwide aviation is expected to grow by 5% annually. If fuel consumption and CO2 emissions were to grow at the same rate, CO2 emissions by worldwide aviation in 2050 would be more than six times their current figure.

Historically, significant fuel efficiency gains have been achieved by operational improvements (e.g. higher load factors, utilization of larger aircraft) and by technical progress (e.g. more efficient engines, lighter airframes). This is expected to continue. As a consequence, aviation fuel consumption is forecast to grow only by 3% annually. Even this, however, implies a more than tripling of CO2 emissions by 2050.[3]

Aviation growth rates are expected to be highest in strongly developing countries, particularly Asia and the Middle East, and lower in regions where aviation is already well developed. For the EU, aviation traffic is expected to grow at an average rate of 3% annually until 2050, implying fuel consumption growth of 2% annually, and hence a more than doubling of CO2 emissions by 2050.

The current worldwide consumption of aviation is about 200 million tonnes kerosene per annum. European consumption was 53 million tonnes[4] in 2010. Total annual consumption of the largest European airlines (Lufthansa group, AF/KLM group and BA/IB IAG group) is about 20 million tonnes.

In awareness of the environmental consequences of continued CO2 growth, IATA members have pledged in 2009 the following goals:

- Improve fuel efficiency by 1.5% per year during the subsequent decade
- Make all industry growth carbon-neutral by 2020
- Reduce net CO2 emissions by 50% by 2050, compared with 2005 levels.

There is widespread recognition that biofuels are expected to play a key role in achieving these goals.

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[2] Member States' National Renewable Energy Action Plans submitted under Directive 2009/28/EC, http://ec.europa.eu/energy/renewables/transparency_platform/action_plan_en.htm
[3] These figures are based on data presented by Booz & Company at the 2011 World Economic Forum in Davos.
[4] SWAFEA estimate

. Environmental efficiency as well as a sound international competitive level playing field for aviation requires a global framework.

The Policy and Regulation Context (from Global policy to National Regulations)

ICAO, the global aviation policy

The International Civil Aviation Organization recognises sustainable alternative fuels as an important pillar within the package of measures needed to be applied in a coordinated manner to strategically reduce greenhouse gas emissions from aviation. ICAO itself has organised workshops and Seminar on sustainable alternative fuels, since 2009.[5]

In October 2010, the 37th session of ICAO Assembly adopted Resolution A37-19 which encouraged Member States and industry to actively participate in further work on sustainable alternative fuels for aviation as part of the basket of measures to limit carbon emissions from international aviation.

Resolution A37-19 adopted by 37th ICAO Assembly in October 2010 notably incorporated the following elements:

- Further endorsement of the global aspirational goal of 2% annual fuel efficiency improvement up to year 2050
- A medium term global aspirational goal from 2020 that would ensure that while international aviation sector continues to grow, its global CO_2 emissions would be stabilized at 2020 levels

Building on the outcomes of the ICAO Aviation and Sustainable Alternative Fuels (SUSTAF) Workshop held in October 2011 and on the discussions of the 194th Session of the ICAO Council, ICAO created in June 2012 the SUSTAF Expert Group to develop recommendations to further facilitate the global development and deployment of sustainable alternative fuels for aviation.

These recommendations are being further elaborated in view of the 38th session of ICAO Assembly in September/October 2013.

The White Paper Roadmap to a Single European Transport Area

On 28 March 2011 the European Commission adopted the White Paper "The Transport 2050 roadmap to a Single European Transport Area"[6]. It sets out to remove major barriers and bottlenecks in many key areas across the fields of: transport infrastructure and investment, innovation and the internal market. The aim is to create a Single European Transport Area with more competition and a fully integrated transport network which links the different modes and allows for a profound shift in

[5] Workshop in February 2009 in Montreal, Workshop in October 2011 in Montreal, side event during Rio+20 on June 2012 in Rio
[6] COM(2011) 144 final of 28.03.2011, see: http://ec.europa.eu/transport/strategies/2011_white_paper_en.htm

transport patterns for passengers and freight. The roadmap includes 40 concrete initiatives for the next decade which will dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050.

In this context the White Paper includes for the first time the ambitious goal of reaching 40% use of sustainable low carbon fuels in aviation by 2050.

"Flightpath 2050: Europe's Vision for Aviation"

The report "Flightpath 2050 Europe's Vision for Aviation" sets out a long-term vision for European aviation in the context of the important challenges ahead. It lays out how and where the European research priorities should be set to bring clear EU-added value, so as to preserve EU growth and competitiveness worldwide, whilst meeting market needs as well as energy and environmental challenges.

It highlights energy and environment as major challenges and underlines the need for further improving the energy efficiency of aircraft and operations together with the need to produce liquid fuels and energy from sustainable biomass as an important part of the energy supply. Among the goals it advocates that Europe be established as a centre of excellence on sustainable alternative fuels, including those for aviation, based on a strong European energy policy.

In its Research and Innovation Agenda Volume 2, ACARE developed a roadmap to support the achievement of its goals and challenges. With regards to alternative sustainable fuels for aviation, the roadmap targets an increasing share starting with 2% in 2020, increasing to 25% in 2035 and reaching at least 40% by 2050 as set out in the Transport White Paper.

Clean Power for Transport: A European alternative fuels strategy

In March 2010 the European Commission established a stakeholder Expert Group on Future Transport Fuels, with the objective of providing advice to the Commission on the development of political strategies and specific actions aiming towards the substitution of fossil oil as transport fuel in the long term, and decarbonising transport, while allowing for economic growth. The European alternative fuels strategy (COM (2013) 17) provides a framework to guide technological development and give confidence to consumers on the market development. It addresses for the first time also the potential of new aviation fuels in such intermodal context[7] and recognises that certain modes and types of transport such as aviation will continue to depend largely on liquid hydrocarbon fuels.

The strategy highlights the need for financing instruments and market incentives to support the construction of biofuel production plants for aviation however these financing instruments have still to be developed.

The Renewable Energy Directive

Directive 2009/28/EC on the promotion of the use of energy from renewable sources ("the Renewable Energy Directive") established mandatory targets to be achieved by 2020 for a 20% overall share of renewable energy in the EU and a 10% share for

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http://ec.europa.eu/transport/urban/vehicles/road/clean_transport_systems_en.htm renewable energy in the transport sector. Furthermore sustainability criteria for biofuels to be counted towards that target were established[8].

This directive applies to biofuels used in aviation, including international aviation when sold in a Member State. Biofuels used in aviation thus count towards meeting the RED target and qualify for incentives by the Member States if they comply with the sustainability criteria Today, 13 voluntary certification schemes, specifically developed to certify the sustainability of biofuels used in the EU, are recognised by the EU Commission[9,10].

The RED requested EC to review the impact of indirect land-use change on greenhouse gas emissions and to address ways to minimise that impact. This resulted in the final proposal for the amendment of the RED directive which was issued on the 17th of October 2012. The aim of the proposal is to:

- limit the contribution that conventional biofuels (with a risk of ILUC emissions) make towards attainment of the targets in the Renewable Energy Directive, (a 5% CAP is being proposed))
- improve the greenhouse gas performance of biofuel production processes by raising the greenhouse gas saving threshold for new installations to 60% now rather than as from 2018.
- encourage a greater market penetration of advanced (low-ILUC) biofuels by allowing such fuels to contribute more to the targets in the RED than conventional biofuels (through multiple counting mechanism)
- request Member States and fuel suppliers to report the estimated indirect land-use change emissions of biofuels.

The proposal mentions also that on the Commission's point of view that after 2020, the biofuels which do not lead to substantial greenhouse gas savings and are produced from crops used for food and feed should not be subsidised.

This proposal is under discussion at the European Parliament, the first reading in the plenary session is planned in September 2013.

Dutch Biokerozine policy:

The Netherlands has included bio kerosene for being part of the obligation and allowing trading them in the form of bioticket.[11]

US Renewable Identification Number (RIN) credits:

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8 Directive 2009/28/EC of the European Parliament and of the Council of 23/04/2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Article 17 Sustainability criteria for biofuels and bioliquids, at pp. L140/36-L140/38.

9 ISCC, RTRS EU RED, Bonsucro EU, RSB EU RED, 2Bvs, RSBA, Greenergy,Ensus, Red Tractor, SQC, Red Cert, NTA 8080 and RSPO RED

10 http://ec.europa.eu/energy/renewables/biofuels/sustainability_schemes_en.htm

11 http://www.agentschapnl.nl/en/programmas-regelingen/dutch-biofuels-policy

In the US, the Environmental Protection Agency (EPA) decided to explicitly include jet fuels as renewable fuels. The EPA is authorized to set annual quotas of biofuel blended into fossil fuels. Fuel operators are obligated to meet certain quotas and are required to submit a certain amount of RINs. This provides opportunities for the market, as these fuel pathways are now eligible for crediting and generating Renewable Identification Numbers (RINs) in accordance with US RFS regulation.

Other policies:

Other policies related to biofuels developments which also apply to aviation are further detailed in ANNEX 1 :

- The European Industrial Bioenergy Initiative (EIBI) of the SET Plan
- EU Emission Trading Scheme (ETS) in which biofuels counts for zero emission
- The consultation on the green paper on "A 2030 framework for climate and energy policies"

Biofuels for the Aviation industry

Recent analysis and reports by the Commission and third parties conclude that there is sufficient *sustainably* produced biomass to meet the EU bioenergy targets by 2020[12,13,14,15]. Nevertheless, many actors such as SAFUG[16] consider further studies must be performed in order to consolidate this conclusion. SAFUG feels there have been first generation mistakes (primarily in terms of ground fuels),which should not be repeated.[17]

Main biomass sources are forestry and agricultural residues, waste materials and inedible energy crops. It is not intended to produce aviation bio kerosenein a way that competes with food production. Wastes and residues (e.g. straw) are particularly desirable as feedstock as they diversify the range of feedstocks used. If cellulosic energy crops or vegetable oils are used as feedstock, sustainability of raw materials depends on their production, in particular with regards to land use. Ultimately the sustainability of a particular biofuel will be determined by comprehensive of the entire supply chain.

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[12] "Real potential for changes in growth and use of EU forests- EUwood", Tender contract N°/TREN/D2/491-2008, see: http://ec.europa.eu/energy/renewables/studies/doc/bioenergy/euwood_final_report.pdf

[13] European Biofuels Technology Platform, "Strategic Research Agenda & Strategy Deployment" http://www.biofuelstp.eu/srasdd/080111_sra_sdd_web_res.pdf

[14] Institute for European Environmental Policy: Mobilising Cereal Straw in the EU to feed advanced Biofuel production

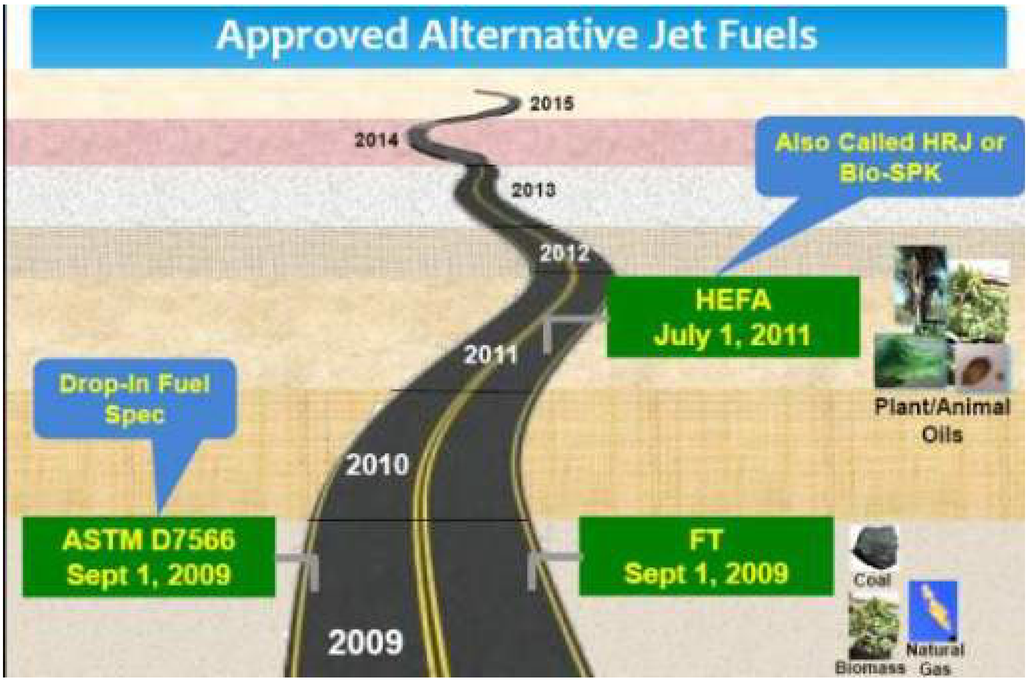
[15] F. Monforti, K. Bödis, N. Scarlat, J.-F. Dallemand: The possible contribution of agricultural crop residues to renewable energy targets in Europe: A spatially exlicit study; in: Renewable and Sustainable Energy Reviews

[16] Sustainable Aviation Fuel Users Group

[17] http://safug.org/assets/docs/iluc-global-proposition.pdf

The main driver for aviation to use alternative fuels is reducing GHG emissions and allow aviation supply to meet demand growth while at the same time the sector diversifies fuel supply. Sustainability of the biofuels is therefore a key prerequisite. Only biofuels that meet stringent sustainability criteria evaluated as above are acceptable to the aviation industry.

The number of pathways potentially suitable to produce aviation kerosene has strongly increased over the last few years. At the writing of the initial Flightpath document in 2011, only three pathways were considered reasonable candidates: Synthetic Fischer-Tropsch (FT) based kerosene produced through biomass gasification, Hydrogenated Esters and Fatty Acids (HEFA) and Hydrogenated Pyrolysis Oils (HPO) produced from lignocellulosic biomass. By now, several additional pathways are in the process of being approved for aviation use (see also Safety and Standards section of this document). The illustrations below show the main alternative biofuels now under review for approval, or already approved. A brief description of the production pathways can be found in the section "Biofuels Technology Status" of this document.



FT = Fischer-Tropsch/ HEFA = Hydroprocessed Esters and Fatty Acids
Source ASTM : certified pathways

Status	Class	Process	Feedstock
Completed			
Annex A1	FT SPK	Fischer Tropsch (FT) derived SPK	Coal, Natural Gas, Biomass
Annex A2	HEFA SPK	Hydroprocessed Fats and Oils (HEFA) derived SPK	Triglyceride Oils
In the Approval Process			
	FT SKA	FT derived SKA	Coal, Natural Gas, Biomass
	ATJ SPK	Fermentation alcohol, oligmerized and hydrotreated (ATJ) derived SPK	Sugar, Alcohol
In Development			
	ATJ SKA	ATJ derived SKA	Sugar, Alcohol
	CH SKA	Hydrothermal Cracking and Cyclization derived SKA	Triglyceride Oils
	CRJ SPK	Catalysis, oligermerized and hydrotreated derived SPK	Sugar, Alcohol
	DSHC SPK	Direct Fermentation to SPK	Sugar
	HEFA SKA	HEFA derived SKA	Triglyceride Oils
	HDCJ SKA	Hydroporcessed Depolymerized Cellulose derived SKA	Lignocellulose
	SAK	Catalysis to SAK	Sugar, Alcohol

SPK Synthetic Paraffinic Kerosene
SKA Synthetic Kerosene with Aromatics
SAK Synthetic Aromatics, Kerosene boiling range

Source : ASTM list of "research" pathways

Most of the above types of biofuels have been supported by the EC under 7th EU Framework Programme (FP7) in the area of bioenergy (see ANNEX 2).

Other transport research projects in support of the development of biofuel for aviation were conducted. They cover feasibility studies, engine tests, feasibility of new pathways, and a case study: biojetfuel production line chain including commercial flights. A short summary of these projects is provided at ANNEX 2

Technical aspects

Safety and standards

Due to safety reasons, all aviation fuels have to meet very strict quality specifications. There is a considerable number of jet fuel specifications in the world, but most of them are obsolete or cover special purpose fuels. In practice, the main jet fuels used in the aviation sector in significant quantities are those meeting the ASTM D 1655[18] "Jet A" and "Jet A-1" specifications[19] and the UK DEF 91-91 standard.

Aircraft can use only those fuels which they are certified to use. Use of any other fuel would require re-certification of the aircraft. In practice that means that any biofuel or biofuel blend has to be formally qualified as being identical to the fuel the aircraft are certified to use, which requires extensive testing to verify that the fuel is essentially equivalent to ASTM D 1655 jet fuel. Such biofuels or biofuel blends are referred to as drop-in fuels[20].

[18] ASTM D 1655 is the quality specification standard for kerosene developed by ASTM International of the US. It is available under http://www.astm.org/standards/petroleum-standards.
[19] "Jet A" specification fuel has been used in the United States since the 1950s and is only available in the United States, whereas "Jet A-1" is the standard specification fuel used in the rest of the world
[20] "Drop-in-fuel" implies that once the fuel meets the ASTM specification, it can be blended up to a certain volume percentage and the final blend will have identical properties to those of ASTM 1655.

Qualification of commercial aviation jet fuel is co-ordinated among the US based ASTM and the UK DEF STAN organisation for Europe. By agreement among the two, the ASTM International aviation fuel subcommittee is leading the qualification process for aviation biofuels. The steps to be followed by this qualification process are governed by ASTM D4054 «Standard Practice for Qualification andApproval Of New Aviation Turbine Fuels and Fuel Additives».

ASTM has developed standard ASTM D 7566 to specify jet fuels produced from other material than crude oil. ASTM D 7566 currently provides specification criteria for Fischer Tropsch (FT) fuels in its annex A1, and Hydroprocessed Esters and Fatty Acids (HEFA) jet fuels in its annex A2[21]. These standards permit blending bio jet fuel with conventional jet fuel from crude oil, up to 50% neat bio fuel content. DEF STAN is mirroring this in Annex D of DEF STAN 91-91 Issue 7, by referring to ASTM D 7566.

FT jet fuel has been approved for several years, and FT SPK jet fuel from coal is already being used commercially in aviation at large scale. No technical problems with its use have been reported. Jet fuel containing FT SPKfrom natural gas has started to become available in large scale from the Pearl plant in Qatar at the end of 2012, and is now routinely being used by Shell up to 25% in blends with conventional kerosene. FT SPK from biomass has not yet been produced in volumes sufficient for evaluation in flight, but is not expected to be chemically different from FT SPKfrom coal or gas. HEFA SPKfuels have been certified for aviation use since July 2011, and have since then been used on evaluation flights by a number of airlines, particularly Lufthansa (1.187 flights with 50% bio fuel blend), KLM (100 flights with 10% bio fuel blend) and Alaska Airlines (75 flights with 20% bio fuel blend). Again, no technical problems with its use have been reported.

Other advanced production processes are currently under evaluation by the ASTM subcommittee. The ATJ (alcohol to jet) process consists of the dehydration of alcohol followed by the catalytic conversion of the resulting olefins to jet fuel products. Direct Sugar to Hydrocarbons (DSHC) to jet fuel involves the yeast-based conversion of sucrose to jet fuel. Other processes include the catalytic conversion of oxygenates, a water-based reaction of triglyceride oils, and high temperature conversion of cellulosic feedstocks to synthetic crude oils (pyrolysis). Approval for some of these processes is tentatively expected as early as 2014.

As part of the ASTM International fuel approval procedure, intensive tests have to be conducted both by the airframe and the engine manufacturers. Some demonstration flights will also be conducted to confirm that the tested biofuels and blends are "fit for purpose"[22].

Emissions

The rationale behind the use of bio kerosene is the reduction of CO2-emissions, plus having an alternative to fossil fuels. However, attention must also paid to emissions

[21] At the time of writing, the most recent release of this standard is D7566 – 12a, also available on http://www.astm.org/standards/petroleum-standards
[22] "Powering the future of flight", Air Transport Action Group, March 2011, see: http://www.atag.org/files/Powering-141456A.pdf

other than CO2 do not result in an increase in other harmful emissions. For this purpose, a Flightpath 2020 workshop on non-CO2 emissions was held in Brussels on 25th April.

The most relevant non-CO2 issues identified are:

- Contrails. This is a high altitude issue with a potential climate impact. Contrails can contribute to greenhouse effects by blocking the radiation of energy from earth back into space, both directly and by inducing cirrus cloud formation. The radiative factor of contrails still is subject to high uncertainty levels. The respective research studies should be reinforced in order to get a scientific consensus in the near future

- NOx emissions. This is primarily a low altitude issue. NOx is potentially dangerous to human health, both directly and via low-altitude ozone formation. There also is a higher altitude effect. NOx is not itself a greenhouse gas, but is causing ozone production with greenhouse impacts. However the effect is more compley as NOx reduces methane, which is another greenhouse gas.

- Ultrafine particles. This is a ground issue directly effecting human health. In most locations the effects of ultrafine emissions from aircraft are dwarfed by the effects from road transport, but for locations directly on the airport high concentrations are possible, potentially creating a workplace issue.

Noise is another aviation related emission, but drop-in biofuels are not expected to have an effect here, because engine performance remains unchanged with drop-in fuels.

The evidence so far for the already certified FT- and HEFA- drop-in biofuels is that they can have a benign influence on non-CO2 emissions, as they have far less aromatics and far less impurities. Studies such as SWAFEA indicated a reduction of soots which could influence positively the formation of contrails. This will however not necessarily be true for other production pathways still undergoing certification, some of which also include the formation of aromatics. For these pathways empirical evidence of their emissions characteristics is still lacking, and research will be needed.

Logistics and blending

Through this ASTM International approval process, bio jet fuel and blends with conventional jet fuel that are produced to ASTM D7566 are also recognised as meeting the conventional jet fuel ASTM D 1655 specification. Consequently, the existing infrastructure (most importantly pipelines) can be used both for transport to and for fuelling at the airport.. Hence, for the blended fuel there are no particular logistical constraints.

However, the blending itself is subject to constraints. In principle, for both FT- and HEFA-fuels a blend ratio of up to 50% is permissible according to the certification standards. However, this is on condition of the blended fuel meeting defined specifications. Depending on the properties of the conventional kerosene available for blending, the blend ratio actually achievable may be considerably lower.

The main limiting factor is likely to be aromatics content, as the blend needs to have an aromatics content of at least 8.4%, due to concerns about preservation of seal tightness. Since both FT- and HEFA-fuels have next to no aromatics content, the conventional kerosene needs to have an aromatics content of at least 16.8% to permit 50% blending. In practice, much of the conventional kerosene produced in Europe has an aromatics content below that figure. Other factors potentially limiting the blend ratio are density and lubricity. A closer investigation of these blending issues is currently performed by Lufthansa on behalf of the European Commission as part of the Flightpath 2020 activities.

Another limiting factor is not technical but linked to the existing fossil fuel infrastructures. Aviation biofuels must be capable of being co-mingled with conventional kerosene in storage tanks, tankers, and when loaded onto a partially fuelled aircraft. This will mean fuel sourced from biomass will become indistinguishable from fuel sourced from fossil resources. This also means current owners of the infrastructure agreement in order to accept new fuels actors.

Ensuring that the renewable jet fuels meet the sector's sustainability criteria will require a tracking system that follows as much as possible the existing supply chain practices. Segregation of aviation fuels at point of delivery (i.e. airports) comes with a substantial penalty, and should be avoided. Consequently, "consumption allowances" should be administered through a process that on the one hand tracks the origin of the renewable material and on the other hand grants the title to those airlines which elect to use the renewable jet fuel. Such a system should combine maximum flexibility with a robust tracking methodology. It seems recommendable such system is based on a mass balance approach. Some additional considerations to be followed can be found in ANNEX 3.

Biofuels Technology Status

There are several advanced European technologies that could be deployed in producing biofuels for aviation.

HEFA derived synthetic paraffinic kerosene is based on triglycerides and fatty acids which can originate from plant oils, animal fats, algae and microbial oil. Hydrogen demand for hydro processing of different feedstock qualities varies, resulting in conversion cost advantages for certain raw materials like palm oil and animal fats. In absence of technical restraints, market forces and legislation are the main forces for oil and fat selection. This process is already approved for a 50% blend by ASTM.

HEFA production is already proven on full commercial scale. Neste Oil operates two 190,000 t/a HEFA plants in Finland and one 800,000 t/a plant each in Singapore and Rotterdam. UOP and its customers have announced several HEFA projects worldwide. In Europe both ENI and Galp Energia have plans for HEFA plants at 330,000t/a each but these are yet to start construction. However, the output from these facilities is designed for diesel replacement in road transport and as such cannot be used for aviation unless some process modifications are carried out on the existing facilities. Although these process modifications entail some costs, these are relative low and the industry knows how to implement them when demand for bio kerosene will appear in the market.

Algal oils can replace vegetable oils in HEFA or similar processes but these will not be commercially available at least within the next 5-8 years. Due to very high infrastructure cost for industrial algal cultivation it is unclear when competitiveness vs. conventional plant oil or other advanced biofuels cost will be achieved. However, due to the fact that in principle there are no issues related to land use, algal oils have attracted significant interest by the aviation sector.

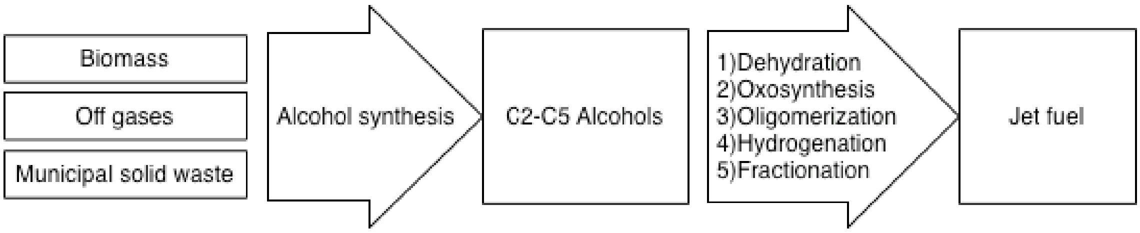
FT derived synthetic paraffinic kerosene is produced via gasification of lingo-cellulosic biomass, intermediate bioenergy carriers, residues or waste followed by gas cleaning and conditioning, hydrocarbon synthesis, hydro processing and product fractionation. Like HEFA, it is already approved for a 50% blend by ASTM.

The FT synthesis is applied in industrial scale processes since decades based on synthesis gas produced from coal and natural gas. The step of high quality syngas production from solid lignocellulosic biomass is however posing some additional challenges, as type and level of synthesis gas impurities depend on the feedstock and the gasification technology and are specific to each combination of those; thus experience from CTL or GTL does not necessarily apply to BTL. After some failed attempts this step is now currently at demonstration stage. StoraEnso and Neste Oil as well as UPM and Carbona have formed two consortia to respectively realize BTL plants on basis of biomass gasification and FT synthesis in Europe. Neste Oil and Stora Enso have operated a demonstration plant in Varkaus, Finland, and the technology was successfully proven. After careful and realistic investment cost calculations the project was put on hold. UPM's project near Strasbourg has been nominated to receive NER300 grants. The annual production capacity will be 100.000 tons of liquid products. Feasibility studies are in progress and an investment decision is expected by early 2014. ForestBtL Oy, a technology company owned by Vapo Oy, aims to construct a synthetic FT plant in Ajos in Finland. The plant will convert sustainable forest residues and tall oil into 3.700 bpd of 2nd generation renewable liquid fuels and is based on high-temperature, entrained flow gasication, followed by Fischer-Tropsch synthesis. The project has also been nominated to receive NER300 grants UHDE together with a number of French companies announced the realisation of a biomass torrefaction pilot plant in combination with a second pilot plant consisting of an entrained flow gasifier and a small pilot scale FT plant under the project name BioTfuel. Another project called Syndièse is led by the French Commissariat à l'Énergie atomique et aux énergies alternatives (CEA), using Air Liquide gasification technology. This project, which is supported by Air France, aims to demonstrate technical and commercial viability at pilot scale. The pilot plant is planned to be built in in Bure-Saudron in France with a biofuel production capacity of 22.000 t/a, using forestry waste as a feedstock The first deliveries are scheduled for 2018. In the UK, Solena is developing a municipal waste to biojet facility using patented plasma gasification technology combined with FT. The planned capacity is 50.000 t/a bio kerosene, with completion of construction by 2015, and the process has potential to be replicated in other UK and European sites.

HPO kerosene is based on pyrolysis oils from lignocellulosic biomass. Pyrolysis oils can be hydrotreated either in dedicated facilities or co-processed with petroleum oils in refineries.

HPO is still at research status. Worldwide, several initiatives exist on developing fast pyrolysis processes. A few of them (e.g. Ensyn/Envergent Technologies (a joint venture between UOP and Ensyn Corp from Canada) and BTG in the Netherlands) are implementing the pyrolysis process on a commercial scale to produce crude pyrolysis oil. Contrary to vegetable oils (VO) pyrolysis oil contains a few hundred different chemical species. For application in the transport sector the crude oil needs further upgrading to produce HPO. One or more hydrogenation steps are required to achieve the desired product quality. The scale of operation for producing the pyrolysis oil can be quite different from the upgrading activities. The latter one might be combined with current refinery operations. Envergent/UOP, for example, is conducting a demonstration project for Pyrolysis and the Upgrading technology to transport fuels at the Tesoro refinery in Hawaii. Contrary to FT and HEFA fuels HPO will still contain a certain amount of aromatic compounds which are currently needed in jetfuel to avoid engine sealing problems. Therefore, HPO may complement HEFA and FT.

The alcohol to jet process (ATJ) is characterised pathways from biomass and other renewable raw materials to jet fuel with alcohols as an intermediate product. See Figure 1. The overall process consists of alcohol synthesis from the raw materials followed by chemical synthesis into jet fuel. An advantage of the ATJ technology is that it can be fully integrated with a wide variety of different front end technologies for the production of alcohol intermediates.



ATJ is currently still at pilot plant scale. Major players are Swedish Biofuels AB in Europe and Gevo in the United States.

The technology called Direct Sugar to HydroCarbons , DSHC , developed by Amyris and Total , produces pure iso-paraffinic molecules by fermentation of any type of sugar, followed by a mild hydrogenation. The first industrial molecule , a C15 hydrocarbon called farnesane , can be safely incorporated in fossil jet-fuel at 10% and ASTM certification is presently under way.

As this versatile molecule is already used for diesel , it is already produced on a commercial scale, up to 50 million liters per year , in the Brotas plant located in Brazil using cane sugar as feedstock. If ASTM certification is obtained by the end of 2013, commercial utilisation of farnesane-containing jet-fuel is possible in Brazil for the 2014 Soccer World Cup. Utilization in Europe is contemplated from 2016 onwards if the right regulatory and economical environment is in place. Further development, in the form of C10 molecules to complement C15, is under way.

Lignin to jet fuel technology (LJF) is under development by Chemtex Italia. It is a chemo-catalytic conversion of lignin into jet fuel. The base concept is the production of aviation biofuels from lignocellulosic biomass through valorization of biorefinery co-products (lignin-rich stream), exploiting the PROESA Technology developed by Chemtex aimed at the production of lignocellulosic ethanol from non-food biomasses.

The process involve the use of the lignin fraction typically obtained as a co-product of the lignocellulosic bioethanol process, Yet the LJF process is flexible enough to use lignin-containing raw materials from other processes. The current raw material is derived from a naturally occurring lignocellulosic biomass, after the majority of the carbohydrate fraction has been biologically converted to ethanol in the Crescentino-Italy plant built up by Chemtex Italia (M&G Group). The lignin rich stream is then subjected to hydrogenation and dehydration steps according to a novel process developed by Chemtex to convert it into more valuable jetfuel and chemicals (such as BTX, widely used as building blocks for the monomers/plastic polymers production). The peculiarity of the LJF process is that it is actually conceived as part of a modern biorefinery whereby a variety of chemical components are generated in conjunction with fuels production, leading to a clear optimization of the cost structure of the LJF process.

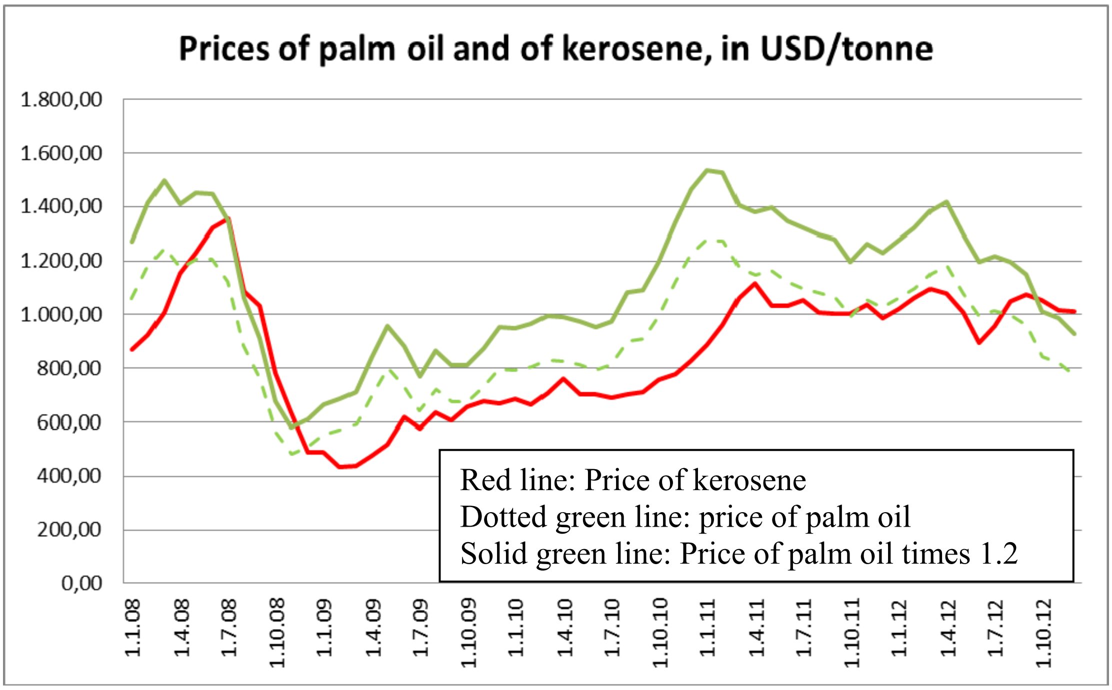
It takes respectively about 2 and 3 years to build a HEFA or a FT plant at commercial scale after taking the respective investment decision. Industrial scale HEFA projects are built with annual capacities of up to 800,000 t/a already today. About 70% of the processed oil feedstock can be converted into jet fuel. The most favoured concepts for Europe based industrial biomass gasification plants, producing FTfuels, are targeting an output of between 100,000 and 200,000 t/a tons FT-fuel per year. Roughly 60 to 70% of the produced FT product can be converted to aviation fuels. The size of FT equipped biomass gasification plants is normally limited by the commercial availability of sustainably produced feedstock at the production site and the economically feasible transport distance. From a sole conversion cost perspective, FT plants should be built as large as possible, however for bulky feedstock like lignocellulosic biomass or waste transport costs are a major constraint on size. One alternative to the use of raw lignocellulosic biomass via gasification is pyrolysis oil or torrefied biomass. Those storable intermediates can be transported from numerous distributed pyrolysis or torrefaction plants to a large centralised unit for FT fuel production. However, total conversion efficiency of this approach is considerably lower compared to direct use of raw biomass and cost advantages are unclear.

The cost of the biofuels

The cost structures of the processes suitable for the production of aviation kerosene can be quite different.

HEFA is not fundamentally different from conventional refining, and the investment required for a HEFA refinery is on the same order of magnitude as that for a conventional refinery. Operating costs per tonne of product are currently still somewhat higher than for conventional kerosene, but are expected to come down to the same level. However, the price of the feedstock material is typically a good deal higher than the price of crude oil, and has typically exceeded even the price of conventional kerosene.

This pricing relationship is best illustrated using the price of palm oil. The average price in 2012 for crude palm oil in Europe has been at ~ USD 1,0000/tonne (~ 761 €/t). This price is highly fluctuating, ranging from 774 to 1,182 USD/tonne in 2012, and from 483 to 1,248 USD/tonne over the five year period 2008 to 2012. Given that it takes 1.2 tonnes of vegetable oil to produce one tonne of bio kerosene,[23] the price of the feedstock has almost always been above that of the conventional kerosene bio kerosene competes with.



Palm oil prices have been used in the prior paragraph due to the ready availability of pricing data. It should however be emphasized that the aviation industry does not wish to use palm oil for the production of aviation kerosene, as this would compete with food use. Certified palm oil is still a major feedstock for the HEFA plants operated by Neste Oil for road use, but is increasingly replaced by waste materials. The HEFA industry expects that the availability of algal and microbial oils as well as inedible oils (camelina, jatropha) will mitigate today's high feedstock price fluctuations in longer term. Generally, the cost of the raw material will remain the critical factor in the HEFA production economics.

In FT processes refining is only the final step after biomass gasification and the FT synthesis itself. The FT production of bio kerosene therefore is more complex than conventional refining, and investment costs are considerably larger. It is estimated that the investment required for a FT plant with an annual production capacity of 200,000 tonnes will require about the same investment as a HEFA plant with four times that capacity, implying higher capital costs..

[23] This is primarily due to the water content in the vegetable oil, which needs to be removed.

Feedstock prices for ligno-cellulosic material are lower than prices for vegetable oils. However there is considerable spatial divergence to extent of this price advantage, as lingo-cellulosic material is not traded over larger distances, and hence is much cheaper in some regions than in others. It takes some seven tonnes of lignocellulosic material to produce one ton of bio kerosene.[24] The current price per tonne of wood pellets is in some regions 85 €/tonne, implying a feedstock price of 600 €/kerosene tonne. Even this is still below the feedstock price for the HEFA process (ca. 900 €/kerosene tonne based on a vegetable oil price of 750 €/tonne and a conversion ratio of 1.2). In other regions the price for woody biomass is considerably lower, and the price difference to vegetable oils much larger.
The other possible production pathways are at an earlier stage of development, and it is difficult to make an economic assessment already now. Some, like the LJF process developed by Chemtex Italia, promise to provide good economic efficiency, however this has not yet been proven at large scale.

Biofuels costs for aviation
From a direct cost perspective it can be expected that all biofuels, capable of meeting aviation fuel quality standards, will be significantly more expensive than fossil kerosene for the aviation industry until 2020.[25] At any rate, regardless of production cost biofuel producers will always have the possibility to sell into the market for road biofuels, as kerosene and diesel are largely identical products. Bio kerosene will therefore have to command at least the same premium as road biofuels, and possibly more, as the product is technically of higher quality and thus more demanding.

In the case of diesel for road use, the difference between biodiesel (FAME) and conventional diesel has come down to 278 USD/tonne in 2012. Average difference from the beginning of 2010 has been 347 USD/tonne. Again, this average masks a high amount of price volatility, with the highest historical difference of 1,000 USD/tonne. Taking the average as the basis for the additional costs of aviation bio kerosene, the total surplus cost of 2 million tons of bio-kerosene would be about 700 million USD. Moreover, advanced road bio fuels are expected to be more expensive than biodiesel, and to depend at least on a double counting mechanism to be economically viable, implying a price difference to conventional diesel possibly twice as high as for first generation biodiesel.

Long term biofuel off-take agreements at prices covering production cost, offering a decent return on invested capital as well as mitigating the premium to be paid by airlines, are a precondition to trigger investment along the entire bio kerosene supply chain. Such agreements can also be a way to sidestep the price competition with road biofuels. However, any arrangement that results in higher costs of jet fuel in Europe compared to the rest of the world would have serious consequences for competition. Even low blends, for example 5-10 % biofuel blend in kerosene, might lead to significant cost imbalances. If this fuel is purchased only by some airlines on a voluntary basis, these will not be able to pass on their costs to the passengers. Passing

[24] This assumes a water content of 40%, which is a usual percentage for traded woody biomass. For completely dry wood, the factor would be more like five to one. However, completely dry wood is an engineering concept. It is not traded on the markets.
[25] A 4. June 2013 press release announced a purchase agreement between USAir and AltAir fuels concerning the supply of bio kerosene at costs competitive to those of conventional fuels, but this project is as yet at the press release stage, and little is knows about the framework conditions.

the extra fuel cost through to the passenger is only possible when a level playing field is achieved. Given the international character of aviation, this will in most cases require a worldwide agreement.

The current price for an allowance to emit one tonne of CO_2 is low and contributes little to closing the gap with biofuel costs.. It is expected that this allowance price will increase in the future, but any forecast is difficult.

Barriers to commercialisation of advanced biofuels

Second generation biofuels or advanced biofuels have made significant technological progress the last few years and under strict and controlled conditions their use in aviation has been proven for FT- and HEFA-derived bio kerosene. However, globally these fuels are existing only at large scale industrial demonstration and there are no commercial plants operating to supply them on a regular basis. Although the optimisation and deployment of the various conversion processes has to be accelerated and the number of new pathways is rapidly increasing, the technology foundations to convert biomass to high quality biofuels are available already today.

However, there are several hurdles that at present prevent commercial deployment of second generation biofuels:

Lack of reliable overall biofuel policy
There is in principle an EU policy in favour of biofuels, but it is subject to frequent change, and political and popular support for biofuels have waned in recent years. The use of food crops for the production of fuel is viewed increasingly critical, and the eventual indirect land use changes associated with such use are currently subject to considerable debate. At the same time, consumers resist the perceived technical risks associated with higher blend ratios, and the higher prices of biofuels.

Much of the current criticism is in fact against first generation feedstocks, which the airline industry – benefitting from the hindsight of a late entry – has avoided from the onset. However, policy does not necessarily make this distinction. For example, even the treatment of second generation feedstocks, and what is recognised as being a second generation feedstock, is currently uncertain. Without a clear and reliable frame of reference, investment will be deterred, and any sector specific initiatives will be difficult.

Although a biofuel refinery can be operated such that the majority of the product is bio kerosene, part of the product stream will inevitably be other liquids, like bio diesel or bio naphta. Moreover, maximizing kerosene production is typically not the best solution in terms of overall efficiency. Hence, any production of bio kerosene will in practice be accompanied by the production of other biofuels. Accordingly, any project aiming to produce bio kerosene is affected by biofuel policy in other sectors, particularly for road fuels.

Lack of policy incentives for aviation biofuels
One critical policy hurdle for commercializing aviation biofuels is the difference in incentives for renewable fuels related to on-road applications and aviation use. The

on-road applications have been encouraged by several measures (e.g. tax breaks and mandates) but these measures do not differentiate between the qualities of the bio-fuels; it is left up to the market operators to use any biofuel as long as the sustaina-bility criteria of the RED and the relevant technical specifications are met.

Regarding the aviation incentives, the only mechanism that has been introduced so far qualifies aviation biofuel as non CO2 emiting fuel within the Emission Trading Scheme (ETS). The benefit of such incentive is undermined by the current difficulties on ETS application to the aviation sector. Therefore, there are no comparable incentives, neither for using biofuels in aviation nor for production of bio-kerosene blendstock. For this reason, existing and planned biofuel production capacity, particularly in HEFA and FT, is in most cases dedicated to the production of biofuels for the road transport. Firstly this is the more profitable business case, if from the same type of biomass a product with typically higher yields and higher market price can be produced, and secondly the continuous production of kerosene blendstock from biomass is to date and at current crude oil prices economically not viable.

In the aviation sector only high physical quality biofuels (e.g. those with low freezing point) can be used to ensure the operability of the jet engines. The current political framework and the international competition lead to a paradox situation, where high quality biofuels are finding applications in road transport although lesser quality biofuels could also satisfy the road transport needs while they can not be used in aviation yet due to the absence of any incentive.

Lack of long term off-take agreements between the biofuel producers and the aviation industry

It only makes sense to build or modify production capacity if there is a market for the product. However, the market for aviation biofuels is non-existent at present. There is no technical advantage for airlines to use biofuels; on the contrary, their use at the moment requires extra effort for blending and quality monitoring arrangements, which come at additional cost.

To help overcome this obstacle, the Flightpath 2020 is working on developing take-off agreements between airlines and biofuel producers, which could guarantee the sale of the product. The airlines involved in the Flightpath 2020 consider to absorb a share of the extra cost associated with the production and logistics of bio kerosene, but can do so only if the fuel itself is no more expensive than conventional kerosene. As described above this is currently not the case, as bio kerosene production costs are considerably higher than those of conventional kerosene. Given the importance fuel costs have for airlines, and the intense competition in airline markets, no airline is in a position to voluntarily pay a biofuel premium for large volumes

Lack of financing

Most biofuel for road transport is currently produced by relatively simple chemical processes. These first generation production processes require relatively little invest-ment, but produce fuels that in several aspects (e.g. freezing point) are inferior to fossil fuels. Such fuels are not suitable for aviation. The production processes necessary for producing aviation bio kerosene are far more complex than first generation processes, and hence require considerably higher investment.

Europe has well developed capital markets, and where a viable and safe business case exists capital will be found. However, due to the factors described above, plus the technical risks associated with the fact that HEFA is the only production process already to have been implemented at large scale, the business case for aviation kerosene is anything but safe. Such projects typically do not satisfy investment criteria. Venture funds might accept such risk profiles, but typically only fund smaller investments, and for shorter durations than those associated with second generation production plants. Moreover, the risk premium associated with venture funding are typically way above what an airline would be willing or able to pay.

Summary

Efficiency gains are not enough to completely offset the carbon footprint of the aviation sector. Biofuels are a viable option and will play an important role in this respect.

Safety and fuel quality specifications are of paramount importance in aviation, but these are not limiting the use of biofuels. The industry is carefully addressing them. ASTM-certified biofuels present no technical or safety problem in flights.

There is policy at EU level for the production and use of biofuels, including in the aviation sector. More attention needs to be given to allowing aviation biofuels access to existing road transport incentives without the imposition of an EU blend mandate causing competitive distortion.

The EU can meet its RED biofuels targets with sustainable resources. Europe's lignocellulosic and HEFA biofuel industries are technology global leaders and pose the know how to move to the deployment phase. However there remain a number of barriers that are proposed to be addressed through the proposed FlightPath:

- Lack of reliable overall biofuel policy framework
- Lack of policy incentives
- Lack of affordable sustainable feedstock for bio kerosene production
- Lack of long term off-take agreements between the biofuel producers and the aviation industry
- Lack of appropriate financial tools to construct first of a kind plants

B. WHERE WE NEED TO GO - AND HOW

There are currently four existing operational HEFA plants that could in principle be modified to continuously convert roughly 60% of the processed biomass to renewable aviation fuel as their main product[26]. However these plants are already profitably serving other markets, hence this capacity is not in practice available. Moreover the existent plants are currently optimized for the production of road fuels, and any changes would imply inefficiencies or additional costs. It is therefore expected that only a small percentage of this capacity will actually be available for the production of aviation bio kerosene, although Neste Oil has indicated a readiness to make available some limited capacity for this purpose.

To achieve the intended goal of two million tons of aviation kerosene in 2020 will therefore require the construction of entirely new plants. At the moment, the only production pathways approved are FT-SPK and HEFA-SPK, and of the two, HEFA-SPK is the only production pathway already implemented at large scale. For the next two or three years, any large-scale (several 100,000 tons/year) installation for the production of bio kerosene will therefore have to be a HEFA plant. Such plants could be built now, and in principle three plants of the Neste Oil Rotterdam size (800,000 tons/year) would be sufficient to produce the FlightPath goal of two million tons of bio kerosene. However, major practical obstacles are the costs of sustainable feedstocks (implying high costs of the bio kerosene produced), and the lack of clarity and stability on which feedstocks are politically and socially acceptable.

FT bio kerosene has not yet been successfully implemented at large scale, hence any production process will first have to be implemented at pilot plant scale. There are currently several FT pilot projects and commercial size first of its kind plants at various stages of planning and implementation, which are expected to be finished between 2015 and 2018. Assuming successful completion of these projects production of FT at larger scale is then a realistic possibility. The size of such plants, and hence the number of such plants required to contribute to the FlightPath goal of two million tons of bio kerosene, is likely to be dependent on the biomass supply concept, with plants using pre-treated biomass (e.g. torrified wood or bio-oil) likely to achieve larger sizes than those based on direct biomass feed.

All other production pathways require both ASTM certification and construction of pilot plants prior to large scale deployment. These steps should however be undertaken in parallel, hence the time until large scale production does not have to be much longer than for FT projects. It is therefore likely that at the end of the decade it will be possible to produce sizeable amounts of bio kerosene from new production pathways. Statements about likely plant sizes are however not possible at this moment, as the new pathways are both various and varied.

[26] These are owned and operated by NESTE Oil. The current capacity (available for the existing plants and planned for the plant under construction) is approximately 2 M tonnes of renewable diesel.

The table below shows the key technology providers and currently planned deployment for biofuels in general.

Project-Location	Technology Type	Planned Total Production Capacity, t/a	Planned Aviation Biofuel Production Capacity, t/a	Start-up Date
Neste Oil-Netherlands	HEFA	800,000	*	2011
Neste Oil-Singapore	HEFA	800,000	*	2010
Neste Oil-Finland 1	HEFA	190,000	0	2007
Neste Oil-Finland 2	HEFA	190,000	15,000	2009
UOP-Italy	HEFA		0	
UOP-Spain	HEFA		0	
BTG-Netherlands	PO	1,000,000	50-100,000 t/a HPO	
Evergent Techn.	HPO		0	
Neste/Stora Enso-Finland	FT		0	
ForestBTL Ajos - Finland	FT	140,000	0	2017
Solena-UK	FT	120,000	50,000	2015
UPM/Carbona - France	FT	100,000	0	2017
CEA - France	FT	22,000	15,000	2018

* = Possibility exists to dedicate tens of thousands of tons capacity to renewable aviation fuel production, if a demand exists

On their own, these plants will fail to provide the FlightPath goal of two million tons of bio kerosene by 2020. However, many of these are pilot plants and can be followed by production ones. It is not the goal of the FlightPath 2020 to voice opinion or give guidance on which of these technologies are to be pursued, as the FlightPath initiative is designed to be technology neutral. We are however confident that technically there will be several ways in which the implementation of the FlightPath goals can be done, and that it will be a question of politics and economics whether it will become a reality.

ANNEX 1: Policy and Regulation: the wider context

The European Industrial Bioenergy Initiative (EIBI) of the SET Plan

At the end of 2007, the Commission proposed the Strategic Energy Technology Plan (SET-Plan),[27] the technology pillar of the EU's energy and climate change policy. A more strategic approach to technology development and deployment is necessary to ensure the achievement of political energy objectives. By the end of 2009, the primary practical instruments and budgetary implications were further developed in the Commission Communication on "Investing into Low Carbon Technologies".[28] This was accompanied by "A Technology Roadmap" presenting the fundamental roadmaps for wind energy, solar energy, the electricity grid, bioenergy, carbon capture and storage, nuclear and the Smart Cities Initiative, which serve as a basis for strategic planning and decision making.[29] These roadmaps were created by the Commission services on the basis of the ongoing work to define the proposed European Industrial Initiatives. For each of the industrial initiatives, technology roadmaps have been developed specifying the investment's estimates and actions required up to 2020.[30]

The European Industrial Initiatives are public-private initiatives led by industry, aiming to accelerate industrial energy research and innovation at the EU and Member States level.[31] They target sectors where cooperating at the Community level will add the most value – technologies for which the barriers, the scale of the investment and risk involved can be better tackled collectively.

The European Industrial Bioenergy Initiative was launched on 16 November 2010 in the SET-Plan conference in Brussels. The initiative is characterised by very innovative technologies and high-risk investments in comparison to all other renewable energy industrial initiatives which aim to improve existing technologies that already have a place in the market and to further facilitate their penetration. The EIBI, on the other hand, aims to bring new technologies onto the market for the first time. The focus of the value chains is on second-generation biofuels production from lignocellulosic biomass, advanced CHP technologies and novel concepts of producing biomass intermediate products.

The EIBI is based on seven value chains, which are summarised in Table 1. In addition to the seven value chains, two horizontal actions are also addressed that are critical for a successful deployment of bioenergy technologies in the EU market. These address the resource availability in the EU and beyond, as well as social acceptance.

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27 COM(2007)723, Communication "European Strategic Energy Technology Plan (SET-Plan), Towards a low carbon future" 2009.

28 COM(2009)519, Communication "Investing in the Development of Low Carbon Technologies (SET-Plan)", 2009.

29 SEC(2009)1295, Commission Staff Working Document Accompanying document to the Communication on Investing in the Development of Low Carbon Technologies (SET Plan) "A Technology Roadmap", 2009.

30 See SEC(2009)1295, "A Technology Roadmap", at pp. 16-52.

31 For an overview of the European Industrial Initiatives, see the Commission website: European Commission, "SET-Plan, towards a low-carbon future", available on the Internet <http://ec.europa.eu/energy/technology/set_plan/doc/setplan_brochure.pdf,

Table 1: EIBI Bioenergy Value Chains and Horizontal Actions[32]

Generic value-chains
Thermochemical pathways (TP)
1: Synthetic liquid fuels and/or hydrocarbons (e.g. petrol, naphtha, kerosene or diesel fuel) through gasification.
2: Bio-methane and other bio-synthetic gaseous fuels through gasification.
3: High efficiency heat & power generation through thermochemical conversion
4: Intermediate bioenergy carriers through techniques such as pyrolysis and torrefaction
Biochemical pathways (BP)
5: Ethanol and higher alcohols from lignocellulosic feedstock through chemical and biological processes
6: Hydrocarbons (e.g. diesel and jet fuel) through biological and/or chemical synthesis from biomass containing carbohydrates
7: Bioenergy carriers produced by microorganisms (algae, bacteria) from CO^2 and sunlight
Horizontal actions (HA)
8: Resource availability and spatial planning
9: Public acceptance

<u>The EU Emission Trading Scheme</u>

The EU Emission Trading Scheme (EC, 2005) is the main instrument of EU policy to combat Climate Change. It was established in 2003 by Directive 2003/87/EC and started operation on 1 January 2005. Initially the EU ETS included only land based industrial installations

From 1 January 2012 aviation activities of aircraft operators that operate flights arriving at and departing from Community aerodromes was also included in the scheme for greenhouse gas emission allowance trading within the Community. The legislation covers 30 States including the 27 EU Member States and Norway, Iceland and Liechtenstein.

Further the ICAO Council meeting 9 November, the Commission proposed on the 12th of November 2012 to "stop the clock" on the implementation of the international aspects of its ETS aviation by deferring the obligation to surrender emissions allowances from air traffic to and from Europe by one year. This means that the EU would not require allowances to be surrendered in April 2013 for emissions from such flights during the whole of 2012. The obligations relating to all operators' activities within EU will remain intact and compliance with the EU law will be enforced in this respect.

[32] See SEC(2009)1295, “A Technology Roadmap”, at pp. 30-34.

The derogation relates only to 2012 emissions and has been agreed by the Council and the European Parliament to facilitate an agreement at the 38th ICAO Assembly (Sept/Oct 2013) on a realistic timetable for the development of a global Market Based Measures (MBM) beyond the 38th ICAO Assembly and on a framework for facilitating the comprehensive application of national and regional MBMs to international aviation, pending the application of the global MBM

The Green Paper

On the 27^{th} of March 2013, the European Commission adopted a Green paper on "A 2030 framework for climate and energy policies". This document launches a public consultation lasting until 2 July, allowing member states, other EU institutions and stakeholders to express their views; for example on the type, nature and level of potential climate and energy targets in a 2030 perspective. The 2030 framework will build on the experience and lessons learnt from 2020 framework and will identify where improvements can be made.

ANNEX 2: 7th EU Framework Programme Biofuel projects

A number of research projects of the 7th Framework Programme have concentrated on the development of new pathways or specific research issues in biofuels for aviation. A summary of the relevant projects is provided in this Annex.

FP7 Overview:

The 7th Framework Programme for research and technological development is the EU´s primary instrument for funding research and demonstration activities over the period of 2007 to 2013.[33] It brings together all research-related EU initiatives under one roof, providing the structure for reaching the EU goals of growth, competitiveness and employment. The total FP7 budget for the seven-year period amounts to 51 billion euros. The EU Member States and the European Parliament have earmarked a total of € 2.35 billion over the duration of FP7 for funding Energy related projects.

FP7 Bioenergy Projects:

Since the start of FP7 in the area of bioenergy, the calls have prioritised large scale demonstration projects with particular emphasis on biofuel production from lignocellulosic biomass and have addressed the most important value chains described in Table 1 below. This has resulted in 10 large-scale demonstration projects that are led by strong industrial consortia aiming to accelerate technology development in key areas and to facilitate their market deployment. The 10 contracts can be divided into four main clusters that represent particular value chains, as shown in Table 2: synthetic biofuels, lignocellulosic ethanol, pyrolysis, and biofuels from algae.[34]

Table 2: EC-Funded Large-Scale Demonstration Projects under FP7

	FIBREEtOH	UPM	UPM	Ethanol	8.6	Fibre	20,000 t/y
	KACELLE	Dong Energy	Inbicon	Ethanol	9.1	Straw	20,000 t/y
	LED	Abengoa	Abengoa	Ethanol	8.6	Corn res.	50,000 t/y
	GOMETHA*	Chetex Italia	Chetex Italia	Ethanol	19.0	Various	80.000 t/y
	SUNLIQUID *	Clariant	Clariant	Ethanol	19.0	Various	60,000 t/y
Pyrolysis	EMPYRO	BTG	BTG	Bio-oil	5.0	Wood	17,400 t/y

Plan", in Pulp and Paper 2010, Helsinki, 1-3 June 2010. For a summary of the ethanol cluster FP7 projects see "Background" in: http://ec.europa.eu/dgs/energy/newsletter/dg/2010/0520newsletter.html (last accessed on 23 September 2010).

Algae	ALL-GAS	Aqualia	Feyecon	Biodiesel & biomethane	7.1	Algae	90t/ha.y algae on 10 ha
	BIOFAT	Abengoa	Alga Fuel	Biodiesel & ethanol	7.1	Algae	90t/ha.y algae on 10 ha
	INTESUSAL	CPI	CPI	Biodiesel	5.0	Algae	90t/ha.y algae on 10 ha
					Total=113.1		

Note: the GOMETHA & SUNLIQUID projects were approved in the 2012 evaluation and are still under negotiations. The EC support is an estimate but it will be close to that indicated above

In the 2013 FP7 Call the topic for biofuel demonstration projects focused on the production and use of biofuels in the aviation sector. Two proposals were shortlisted for support, however, since both these proposals are at the early stages of negotiations little information can be provided at present. The first project with title "Production of fully synthetic paraffinic jet fuel from wood and other biomass" (acronym: BFSJ) is led by Swedish Biofuels and aims to produce bio-kerosene via the ethanol route with key partners Abengoa Bioenergy, Lufthansa, SkyEnergy and LanzaTech with about 56 and 28 Million Euro respectively for total project cost and EC requested support. The second project with title "2000 ton/y insudtrial scale demonstration biorefinery on lignin based aviation fuel" (acronym: BIOREFLY) is led by Chemtex Italia and aims to produce bio-kerosene from the lignin residue of a lignocellulosic ethanol facility with key partner Agusta Westland with about 26 and 14 Million Euro respectively for total project cost and EC requested support.

According to the call specifications in both projects flights will be undertaken with the biofuels produced. The negotiations of both projects are expected to be completed within the next 4 months and the projects should start before the end of the year.

FP7 Transport Projects:

ITAKA: (Initiative Towards sustAinable Kerosene for Aviation)

ITAKA will look at removing the barriers to the use of sustainable biofuels in aviation and therefore will contribute to the annual production target of two million tonnes of biofuel for aviation by 2020.

ITAKA will test the use of sustainable renewable aviation fuel in existing logistic systems and in normal flight operations in Europe. The project will also link supply and demand by establishing relationships among feedstock growers and producers, biofuel producers, distributors, and airlines.

As feedstock, ITAKA targets European camelina oil and used cooking oil, in order to meet a minimum of 60% on greenhouse gas emission saving compared to the fossil jetA1. The project aims to certify the entire supply chain of the renewable aviation fuel, based on the Roundtable on Sustainable Biofuels (RSB) EU RED standard. In addition, the production and use of camelina as a biofuel feedstock will also be assessed with regards to its contribution to food and feed markets and its potential impact on direct and Indirect Land Use Change (ILUC). The research will also evaluate the economic, social and regulatory implications of the large-scale biofuels utilisation in aviation.

Consortium members include companies and research centres leaders in: feedstock production (BIOTEHGEN and Camelina Company España); renewable fuel production (Neste Oil and RE-CORD); fuel logistics (CLH and SkyNRG); air transport (Airbus, EADS IW UK, Embraer and SENASA); and sustainability assessment (EADS IW France, EPFL and MMU).

SOLAR JET (Solar chemical reactor demonstration and Optimization for Long-term Availability of Renewable JET fuel)

The aim of the SOLAR-JET project is to demonstrate a carbon-neutral path for producing aviation fuel, compatible with current infrastructure, in an economically viable way. The SOLAR-JET project will demonstrate on a laboratory-scale a process that combines concentrated sunlight with CO2 captured from air and H2O to produce kerosene by coupling a two-step solar thermochemical cycle based on non-stoichiometric ceria redox reactions with the Fischer-Tropsch process. This process provides a secure, sustainable and scalable supply of renewable aviation fuel, and early adoption will provide European aviation industries with a competitive advantage in the global market. These efforts are further complemented by assessments of the chemical suitability of the solar kerosene, identification of technological gaps, and determination of the technological and economical potentials..The fuel is expected to overcome known sustainability and/or scalability limitations of coal/gas-to-liquid,bio-to-liquid and other drop-in biofuels while avoiding the inherent restrictions associated with other alternative fuels, such as hydrogen, that require major changes in aircraft design and infrastructure.
The process demonstrated in SOLAR-JET eliminates logistical requirements associated with the biomass processing chain and results in much cleaner kerosene and represents a significant step forward in the production of renewable aviation fuels.

Consortium members: BAUHAUS LUFTFAHRT (Germany), Eidgenössische Technische Hochschule Zürich (Switzerland), DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV (Germany), SHELL GLOBAL SOLUTIONS INTERNATIONAL B.V. SHELL Netherlands, ARTTIC (France)

CORE JET (Coordinating research and innovation of jet and other sustainable aviation fuel)

The project CORE-JetFuel will evaluate the research and innovation “landscape” in order to develop and implement a strategy for sharing information, for coordinating initiatives, projects and results and to identify needs in research, standardisation, innovation/deployment, and policy measures at European level. Bottlenecks of research and innovation will be identified and, where appropriate, recommendations for the European Commission will be elaborated with respect to re-orientation and re-definition of priorities in the funding strategy.
The consortium will cover the entire alternative fuel production chain in four domains: Feedstocks and sustainability; conversion technologies and radical

concepts; technical compatibility, certification and deployment; policies, incentives and regulation. CORE-JetFuel will ensure cooperation with other European, international and national initiatives and with the key stakeholders in the field.

The expected benefits are enhanced knowledge of decision makers, support for maintaining coherent research policies and the promotion of a better understanding of future investments in aviation fuel research and innovation, in alignment with the ACARE Strategic Research and Innovation Agenda (SRIA) as well as with the ATAG goals of future emission reduction in aviation.

Consortium members: Agency for Renewable Resources (FNR), SENASA, Bauhaus Luftfahrt (BHL), WIP , IFP, EADS Innovation Works and numerous external experts from science, industry and politics.

ALFA-BIRD (Alternative Fuels and Biofuels for Aircraft Development)

ALPHA BIRD started in July 2008 and ended in June 2012. ALFA-BIRD was aiming at **viable technical solutions**. Its objective was to investigate and **develop a variety of alternative fuels** for the use in aeronautics.
The main challenge in the project work was developing fuels that meet the very strict operational constrains in aviation (e.g. flight in very cold conditions), and were compatible with current civil aircraftTo address this challenge, ALFA-BIRD gathered a **multi-disciplinary consortium** with key industrial partners from aeronautics (engine manufacturers, aircraft manufacturers) and fuel industry, and research organizations covering a large spectrum of expertise in fields of biochemistry, combustion as well as industrial safetyThe most promising solutions have been examined during the project, from classical ones (plant oils, synthetic fuels) to the most innovative, such as new organic molecules. A detailed analysis of **4 new fuels was performed** with tests in realistic conditions.
It covers a number of areas, including:

- study of possible alternative fuels for use in aviation;
- chemical analysis of the "best" fuel;
- improved formulation of biofuels;
- new injection systems;
- modeling of injection and combustion;
- compatibility with aircraft fuel systems;
- production of new fuels.

The first fuel selection matrix has been designed around **three main axes**, covering a wide range of possible alternative fuels from short term to long term:

- paraffinic fuels, with hydrotreated vegetable oils and synthetic fuels
  (XtL), in a short / middle term vision

- naphthenic fuels, representative of new production processes such as
  coal or biomass liquefaction in a middle term vision
- oxygenated fuels, such as higher alcohols or furanic compounds, in a
  long term vision.

The 4 fuels selected were **FSJF**, **FT-SPK, a blend of FT-SPK and 50% naphthenic cut, and a blend of FT-SPK and 20% hexanol**. This fuel matrix offers the possibility to evaluate the potential of different chemical families which are paraffinic compounds, naphthenic compounds and oxygenated compounds. This fuel matrix was also representative of a short, middle, and long term view. The information collected during the tests have been used **to prepare the environmental and economical impact assessment**, which was the basis for the elaboration of the future strategy for the use of alternative fuels for aircraft.

SWAFEA

The SWAFEA European study was initiated to investigate the feasibility and impacts of the use of alternative fuels in aviation. The goals were to develop a comparative analysis of different fuels and energy-carrier options for aviation on the basis of the available knowledge, as well as to propose a possible vision and roadmap for their deployment in order to facilitate and support future policy decisions.

The SWAFEA study was initiated in February 2009 by the European Commission's Directorate General for Mobility and Vehicles as part of its general policy for mitigating climate change and contributing to Europe’s Energy security as well as economic growth.
The study encompassed all aspects of the possible introduction of alternative fuels in aviation using a highly multidisciplinary approach. This included technical, environmental, and economic assessments.

The purpose of the technical component of the study was to complement available data regarding technical suitability of alternative fuels with additional investigation and testing.

The environmental and economic assessments both consisted of in-depth analyses of the impact of various fuel production pathways, from feedstock to fuel, through the entire life-cycle. The environmental component also included societal impacts of fuel production, while the economic component studied the required fuel production infrastructure in addition to the cost breakdown of various alternative fuels.

The study delivered its findings and recommendations in April 2011.

The technical assessment performed in the frame of SWAFEA aimed at complementing the existing works on Fischer-Tropsch (FT) and HEFA (hydroprocessed vegetable oils and animal fats) synthetic paraffinic kerosenes, focused on well-established processes and final products that clone crude-oil based kerosene molecules, by investigating possible solutions beyond these first candidate fuels (impact of synthetic kerosene properties, impact of blending ratio, suitability of naphtenic compounds from liquefaction, potential of FAE).

As part of the environmental assessment of alternative fuels, life cycle analysis was performed for Fischer-Tropsch fuels and HEFA for various type of feedstock evidencing that significant emissions reductions could be achieved with biofuels provided that land use change emissions were carefully controlled. Potential impacts of alternative fuels on radiative forcing through their atmospheric impacts (contrails and high altitude chemistry) were also studied.

An analysis of the potential availability of biomass for energy use up to 2050 was performed taking into account sustainability criteria in accordance with the European Directive on Renewable Energy. The analysis, although containing inherent high uncertainties, outlined the challenge associated with the highest emissions reduction target of aviation and the need for further research on more efficient biomass and processes.

Last, an economic analysis was carried out within SWAFEA, essentially on HEFA and FT biomass-to-liquid (BTL), to evaluate how biofuels compare with conventional jet fuel and which measures could be required for their deployment. The analysis concluded that neither BTL nor HEFA solutions are initially cost competitive with conventional jet fuel while in the longer term their viability depends heavily on the possibility to secure "low price" feedstock supply. Specific policy measures and incentives are thus required to initiate the deployment of biofuels.

Consortium Members : Airbus, AirFrance, Altran, Bauhaus Luftfahrt, Cerfacs, Concawe, DLR, EADS-IW, Embraer, Erdyn, Iata, Ineris, IFPEN, Onera, Plant Research International (WUR), Rolls-Royce UK and Rolls-Royce Deutschland, Shell, Snecma, University of Sheffield

DREAM (Validation of radical engine architecture systems)

DREAM is a large multinational FP7 R&T project which is the response of the engine community to commercial and environmental pressures that have come about mainly as a results of two main factors:

- The demand to reduce CO2 has increased considerably since the publication of the ACARE goals
- The increasing cost and future availability of Jet A1 fuel.

DREAM Sub-Project 5 aimed at demonstrating that alternative fuels could be used in modern aircrafts and engines. This demonstration was performed with an existing and available fuel (2 alternative drop-in fuels have been selected: a 50% GTL - 50% Jet A1 blend provided by Shell and a 50% HVO - 50% Jet A1 blend made of camelina oil provided by UOP) on a turboshaft engine and a paper work extension to aero-engines was performed.

The impact of using these fuels was evaluated both on aero-engine fuel systems and on aircraft fuel systems through the following tests:

- Ageing tests on usual elastomers with both fuels to evaluate elastomers compatibility,
- Fuels system components tests: component characterization, ageing tests, self-suction capabilities,
- Engine endurance test.

The tests concluded that the fuel systems performances with synthetic fuels are similar to performances with Jet-A1. No major disparity has been found between alternative fuels and reference Jet-A1 during the combustion test conducted with small helicopter turboshaft engine.

- It was also concluded that alternative fuels can be used in an aero-engine without major modification. The overall behaviour of the engine with HVO blend is consistent to engine behaviour with Jet-A1. The endurance with HVO blend was successful. HVO effects on Emission Index (EINOx, EICO, EIHC) compared to Jet A1 are lower than engine to engine variability. HVO effects on Smoke Number levels compared to Jet A1 are lower than the uncertainty of the measurement process. The project validated also the fuel system functional requirements in terms of "compatibility with materials" and "lubrication of the fuel system components".

Annex 3: Chain of Custody considerations

Ensuring that the renewable jet fuels meet the sector's sustainability criteria will require a tracking system that follows as much as possible the existing supply chain practices. Segregation of aviation fuels at point of delivery (i.e. airports) comes with a substantial penalty, and should be avoided. Consequently, "consumption allowances" should be administered through a process that on the one hand tracks the origin of the renewable material and on the other hand grants the title to those airlines which elect to use the renewable jet fuel. Such a system should combine maximum flexibility with a robust tracking methodology. It seems recommendable such system is based on a mass balance approach.

An effective system will need to be developed by the various stages in the supply chain. For discussion purposes, the following considerations should be taken into account:

- Raw materials would have to meet the EU sustainability criteria at a 100% level (thus avoiding any differences in yields and resulting allocation issues)
- Raw material suppliers should be fully certified by appropriate verification bodies
- Converters can only source from duly certified suppliers
- Converters issue renewable fuel certificates down the supply chain
    - This is the stage where the certificates originate, NOT the raw materials stage
    - The advantage is that there will be no need to reconcile input vs output (yields)
- Renewable jet fuel will be blended up to an agreed maximum percentage into Jet fuel supplied to traders and /or airports, and the fuel will meet the Jet A1 specifications. The certificates follow the subsequent supply stages.
- Certificates will be provided to those airlines which wish to use them
    - At this point the physical molecules will be separated from the certified molecules
    - Theoretically, airlines can obtain 100% certification even if they physically take a (e.g.) 20% blend (as long as other airlines do not take/require any certificates)
- Certificates will be redeemed to fulfill the ETS obligations

Verification should be conducted by independent and accredited agencies. It is envisioned that the certificates are transferred through an electronic system with proper security safeguards. Ultimately, the system could be integrated into the general ETS trading system.