2 million tons per year:

A performing biofuels supply chain for EU aviation

<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.

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

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The key findings of the 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: ENER-biofuels-flight-path@ec.europa.eu quoting "Comments in Aviation Biofuel Flightpath".

The views and opinions expressed in this technical note cannot be held to reflect views of the European Commission or any of its departments or of any other organisation mentioned above.

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

PREAMBLE

This Implementation Plan proposes a Flightpath, for the period 2011-2020 for deploying sustainably produced paraffinic biofuels in aviation. 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.

It is envisaged that the Implementation Plan will be approved on its general lines by the community of stakeholders from aviation, the biofuel producers, Member States and the civil society during a workshop to be held on 18 May 2011 in Brussels. This will be followed by a presentation to the public at the 49th International Paris Air Show Le Bourget.

However, the various actions on the Flightpath will need to be further streamlined and clarified after the Paris Air Show. Depending on the outcome of the discussions with the stakeholders during the Workshop, some adaptation may also be necessary.

This initiative falls under the European Industrial Bioenergy Initiative of the EU SET Plan.

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.

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[1]. 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 paraffinic biofuels that are fit for purpose by the aviation sector.

The objective of this position-paper is to set out milestones to facilitate the deployment of 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 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 4.5% annually. If fuel consumption and CO2 emissions were to grow at the same rate, CO2 emissions by worldwide aviation in 2050 would be nearly 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.[2]

Aviation growth rates are expected to be highest in strongly developing countries, particularly Asia, and lower in regions where aviation is already well developed. For the EU, aviation traffic 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[3] in 2010. Total annual consumption of the largest European airlines (Lufthansa group, AF/KLM group and BA) is about 20 million tonnes.

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

- Improve fuel efficiency by 1.5% per year during the subsequent decade
- Make all industry growth carbon-neutral by 2020

[1] 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

[2] These figures are based on data presented by Booz & Company at the 2011 World Economic Forum in Davos.

[3] SWAFEA estimate

- 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.

From 2012, aviation will be included to the EU Emission Trading System[4,5]. Allowances for the aviation sector are determined as a percentage of 2005 emissions. A proportion of these allowances will be allocated to airlines based on their individual activity in 2010. The shortfall will be met by purchasing allowances through auctions and carbon markets. This system covers both EU and Non-EU carriers.

Environmental efficiency as well as a sound competitive level playing field for a global aviation requires a global framework. In October 2010 the ICAO Assembly[6] recognised the EU ETS and adopted resolution 17/2 requesting the UN Council to explore the feasibility of a global ETS for aviation.

Unless the aviation sector will implement adequate and effective measures it is expected that by 2020 EU airlines will have to pay significant amount towards in buying credits under the ETS scheme. ICAO Resolution 17/2[7] calls for such revenues to be applied towards measures to reduce CO2 emissions from aviation which is also encouraged by the ETS Directive.

The Policy Context

The Renewable Energy Directive

In 2007, the European Union set its climate and energy targets for 2020: to achieve a 20 % share of renewable energy, a 20 % improvement in energy efficiency and a 20 % reduction of greenhouse gas (GHG) emissions by 2020. The Renewable Energy Directive (RED) that followed set a target that 10% of all energy in the transport sector must come from renewable energy sources and the European Union also adopted sustainability criteria for biofuels to be counted towards that target.[8] Only those biofuels complying with the sustainability criteria set by the RED can qualify for the targets and incentives by the Member States.

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[4] The EU Emissions Trading System (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. Being the first and biggest international scheme for the trading of greenhouse gas emission allowances, the EU ETS covers some 11,000 power stations and industrial plants in 30 countries. See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2003L0087:20090625:EN:PDF

[5] See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:008:0003:0021:EN:PDF

[6] The International Civil Aviation Organization ICAO is a specialised agency of the United Nations. The aims and objectives of ICAO are to develop the principles and techniques of international air navigation and to foster inter alia the planning and development of international air transport to ensure safe and orderly growth.

[7] Annex to resolution 17/2, item m

[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.

The Renewable Energy Directive applies also 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 if they comply with the sustainability criteria.

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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),[10] 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".[11] 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.[12] 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.[13]

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.[14] They target sectors where cooperating at the Community level will add

[9] 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.

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

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

[12] 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.

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

[14] 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,

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.

Table 1: EIBI Bioenergy Value Chains and Horizontal Actions[15]

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 System</u>

The EU Emissions Trading System (EU ETS)[16] is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial

[15] See SEC(2009)1295, "A Technology Roadmap", at pp. 30-34.
[16]Directive 2003/87/EC, see:
http://eur lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:338:0018:0023:EN:PDF

greenhouse gas emissions cost-effectively. Being the first and biggest international scheme for the trading of greenhouse gas emission allowances, the EU ETS covers some 11,000 power stations and industrial plants in 30 countries.

Launched in 2005, the EU ETS works on the "cap and trade" principle. This means there is a "cap", or limit, on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations in the system. Within this cap, companies receive emission allowances which they can sell to or buy from one another as needed. The limit on the total number of allowances available ensures that they have a value. The aviation sector will start in 2012 to participate in this system[17].

At the end of each year each company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut where it costs least to do so. The number of allowances is reduced over time so that total emissions fall.

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"[18]. 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 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.

Clean Transport Systems and Future Transport Fuels

Climate protection and security of energy supply both lead to the requirement of building up sustainable energy supply to transport for the time horizon of 2050. As also described in the Transport White Paper, the aim of the Clean Transport Systems (CTS) initiative, scheduled for early 2012, is to present a comprehensive long-term strategy to meet the energy demand of the transport sector from alternative and sustainable sources, capable to substitute oil in all modes in the long term, including measures to take in the short and medium term.

Alternative fuels are a key option to decarbonise transport, by gradually substituting the fossil energy sources. 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

[17] Directive 92/109/EEC, see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:286:0014:0016:EN:PDF

[18] COM(2011) 144 final of 28.03.2011, see: http://ec.europa.eu/transport/strategies/2011_white_paper_en.htm

actions aiming towards the substitution of fossil oil as transport fuel in the long term, and decarbonising transport, while allowing for economic growth. The report was finalised in January 2011. It addresses for the first time also the potential of new aviation fuels in such intermodal context[19] and recognises that certain modes and types of transport such as aviation or long distance road transport will continue to depend largely on liquid hydrocarbon fuels whilst urban or short distance road transport has also other alternatives such as hybrid and electric propulsion or fuel cells.

ICAO and the global aviation policy context

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 several workshops on sustainable alternative fuels, including the Civil Aviation Alternative Fuels Conference in November 2009 in Rio de Janeiro, Brazil. The next specific workshop on alternative aviation fuels is foreseen on 18 to 20 October 2011 in Montreal (preparation ongoing).

Research and Innovation: "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 aircrafts 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.

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[20,21]. Main biomass sources are forestry and agricultural residues, waste materials and energy crops. 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 on a case by case evaluation of the entire supply chain.

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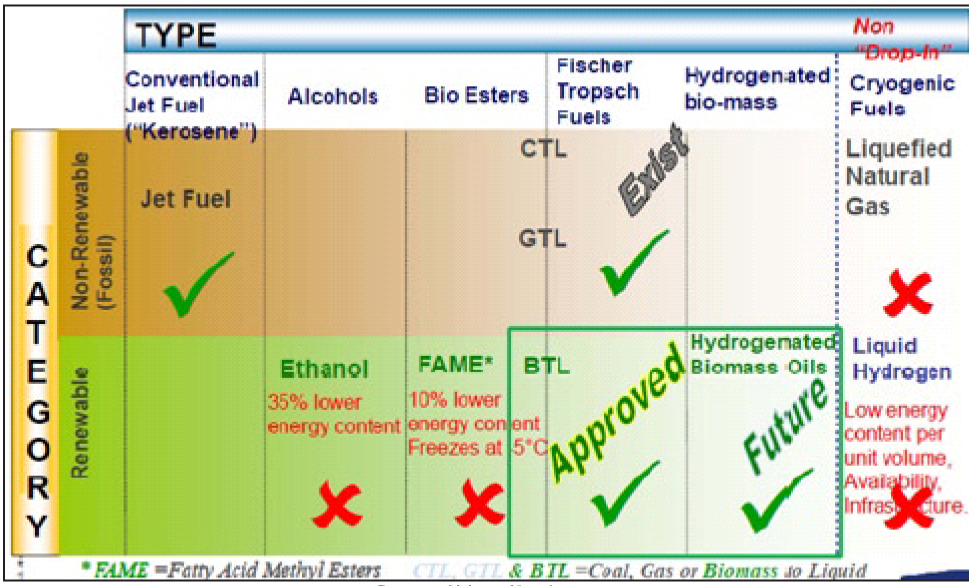
http://ec.europa.eu/transport/urban/vehicles/road/clean_transport_systems_en.htm

[20] "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

[21] European Biofuels Technology Platform, "Strategic Research Agenda & Strategy Deployment" http://www.biofuelstp.eu/srasdd/080111_sra_sdd_web_res.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 as specified by the RED are acceptable to the aviation industry.

Among the different qualities of biofuels, at present three types are favoured to be used in aviation jet engines blended with kerosene: Synthetic Fischer-Tropsch (FT) based kerosene produced through high temperature biomass gasification, Hydrogenated Vegetable Oils (HVO) and Hydrogenated Pyrolysis Oils (HPO) produced from lignocellulosic biomass. The figure below, produced by Airbus, shows the main options for alternative biofuels in aviation and compares the status of the biofuels to that of fuels form fossil origin.



Source: Airbus, March 2010

Source Airbus

FT kerosene is produced via lignocellulosic biomass gasification followed by gas cleaning and synthesis over appropriate catalysts and already today is approved for a 50% blend by ASTM (see section on Safety and Standards below).

HVO is based on triglicerides and fatty acids which can originate from plant oils, algae and microbial oil. Hydrogen demand for hydrogenation 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.

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. Today pyrolysis oil is at the edge of research towards demonstration level.

Algal oils can also replace vegetable oils in HVO 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.

Direct conversion of sugars to hydrocarbon fuels is technically feasible but it is still in the early research phase, thus it will not play any significant role by 2020.

All the above types of biofuels are amongst the value chains prioritised by the EIBI. Most of them have been supported by the EC under 7th EU Framework Programme (FP7).

Contribution from 7th EU Framework Programme

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.[22] 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.

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.[23]

In the remaining time of FP7, the topics will focus on bringing support to the implementation of the EIBI objectives, i.e. for demonstration and pilot actions providing solid basis the first full-scale commercial plants, and medium to longer research for the next generation of technologies.

[22] Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013).For FP7 in general see: http://cordis.europa.eu/fp7/home_en.html; for energy under FP7 see: http://cordis.europa.eu/fp7/energy/home_en.html (last accessed on 23 September 2010).

[23] For a summary of the EC funded projects see Kyriakos Maniatis, "European Union policy measures and support for the promotion of next generation and advanced biofuels" in World Biofuels Markets, Amsterdam 15-17 March 2010, and "The European Industrial Bioenergy Initiative of the EU SET 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).

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

EC Biofuel Cluster	Contract Acronym	Coordinator	Contract Technology Provider	Biofuel	EC Support € M	Biomass	Production Capacity
Synthetic	OPTFUEL	VW	Choren Industries	Fischer-Tropsch	7.8	Wood	15,000 t/y
	BIO DME	Volvo	Chemrec	Dimethyl-ether	8.2	Black Liquor	600 t/y -150 days operation)
LG EtOH	BIOLYFE	Chetex Italia	Chetex Italia	Ethanol	8.6	Various	40,000 t/y
	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 resd.	50,000 t/y
Pyrolysis	EMPYRO	BTG	BTG	Bio-oil	5.0	Wood	17,400 t/y
Algae	ALL-GAS	Aqualia	Feyecon	Biodiesel & biomethane	7.1	Algae	90t/ha.y algae
	BIOFAT	Abengoa	Alga Fuel	Biodiesel & ethanol	7.1	Algae	90t/ha.y algae
	INTESUSAL	Centre of Process Innovation	Centre of Process Innovation	Biodiesel	5.0	Algae	90t/ha.y algae
					Total=75.1		

Safety and standards

Due to safety reasons, all aviation fuels have to meet very strict quality specifications. There is a considerable number of kerosene specifications in the world, but most of them are obsolete or cover special purpose fuels. In practice, the main kerosenes used in the aviation sector in significant quantities are those meeting the ASTM D 1655[24] "Jet A" and "Jet A-1" specifications[25]and the UK DEF 91-91 standard.

Aircrafts 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 certified as being equivalent to ASTM D 1655 kerosene in order to qualify for use in the existing aircraft fleet. Such biofuels or biofuel blends are referred to as drop-in fuels[26].

Certification of commercial aviation kerosene is co-ordinated among the US based ASTM and the UK DEF STAN organisation for Europe. In the case of aviation biofuels, the two bodies have agreed that the certification is co-ordinated by ASTM. ASTM has developed standard ASTM D 7566 to specify ASTM D 1655 kerosenes produced from other material than crude oil. ASTM D 7566 currently covers Fischer Tropsch fuels in its annex A1. DEF STAN is mirroring this in Annex D of DEF

[24] ASTM D 1655 is the quality specification standard for kerosene developed by ASTM International of the US
[25] "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
[26] "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.

STAN 91-91 Issue 7, by referring to ASTM D 7566. Currently no activities are on-going or planned to develop such standard for HPO.

A second annex covering HVO fuels is in the final stages of ASTM approval. Official publication of the specification is currently expected 1. August 2011.Approval of kerosene from hydrogenated pyrolysis oil is far less advanced. Some initial discussions with producers have taken place, but there is as yet no schedule for qualification.

As part of the ASTM International fuel approval procedure, intensive tests have been conducted both by the airframe and the engine manufacturers. Some demonstration flights have also been conducted and confirmed that the tested biofuels and blends are "fit for purpose"[27].

Since through this ASTM International approval process, certain types of bio kerosene and blends with conventional kerosene are recognised as meeting the conventional jet fuel ASTM D 1655 specification, the existing infrastructure (most importantly pipelines) can be used both for transport to and for fuelling at the airport. Thus the supply and logistics of certified drop-in biofuels blends present no problem in this respect.

Biofuels Technology Status

There are several advanced European technologies that could be deployed in producing biofuels for aviation (see Annex 1).

HVO production is already proven on full commercial scale. Neste Oil operates two 190,000 t/a HVO plants in Finland and an 800,000 t/a plant in Singapore. The commissioning of another 800,000 t/a HVO plant is planned for mid 2011 in Rotterdam. UOP and its customers have announced several HVO projects worldwide. In Europe both ENI and Galp Energia have plans for HVO plants at 330,000t/a each but these are yet to start construction.

The FT synthesis is applied in industrial scale processes since decades based on synthesis gas produced from coal and natural gas. The critical step of high quality syngas production from solid lignocellulosic biomass is currently at demonstration stage. CHOREN Industries is in the commissioning phase of a 13.000 t/a demonstration plant in Germany and also is involved in the development of several industrial scale FT projects. StoraEnso and Neste Oil as well as UPM and Carbona have also formed two additional consortia to realize BTL plants on basis of biomass gasification and FT in Europe. Neste Oil and Stora Enso have operated their demonstration plant since 2009 in Varkaus, Finland. UHDE together with a number of French companies announced the realisation of a small pilot scale FT plant using biomass and/or torrefied material – BioTfuel and project led by CEA in Bure-Saudron. In the UK, Solena is developing a waste to biojet facility using patented plasma gasification technology combined with FT. The planned capacity is 50.000 t/a

[27] "Powering the future of flight", Air Transport Action Group, March 2011, see: http://www.atag.org/files/Powering-141456A.pdf

biojet, with full production by 2014 and the process has potential to be replicated in other European sites.

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 HVO 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 HVO and FT.

It takes respectively about 2 and 3 years to build a HVO or a FT plant at commercial scale after taking the respective investment decision. Industrial scale HVO projects are built with annual capacities of up to 800,000 t/a already today. About 60% of the processed oil feedstock can be converted into jet fuel. The most favoured concepts for Europe based industrial biomass gasification plants, producing FT kerosene, are targeting an output of about 200,000 t/a tons FT-fuel per year. Roughly 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. From a sole conversion cost perspective, FT plants should be built as large as possible. 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 HVO and ligno-cellulose based FT and HPO processes are fundamentally different: HVO requires a modest upfront capital investment and production cost is highly dependent on vegetable oil feedstock prices to the extent that approximately 60-75% of the final biofuel cost is made up of the original raw material. In early 2011 crude palm oil is trading at ~ € 740/t and canola oil at roughly € 900/t. The HVO industry expects that the availability of algal oils and inedible oils (camelina, jatropha) will mitigate today's high feedstock price fluctuations in longer term. Generally, the cost of the raw material will be the critical factor in the HVO production economics.

Ligno-cellulose based FT and HPO biofuels have lower exposure to raw material cost. Based on a raw material price of 80 €/t dry matter, the feedstock price component of

FT fuel is ~ 0.3 € per litre. However, FT fuels face higher conversion costs than HVO's due to more complex production processes. This is particularly relevant at the current initial stage, as from engineering practice the costs of a new product start to reduce significantly from the 3rd plant of a new technology. Depending on specific site conditions it can be assumed that the conversion cost share of biomass based FT-fuel will decrease from roughly 1 €/l in industrial first of its kind projects to a range of 0.7-0.8 €/l with learning curve effects and economies of scale if several large scale gasification/FT plants are realized until 2020. Additional conversion cost reduction is expected after 2020 based on general process optimization and industry typical investment cost reduction referring to a progress ratio of ~ 85% with each duplication step of cumulative capacity[28]. Anticipating that raw material prices for HVO and FT biofuels are subject to a similar dynamic, it can be anticipated that FT fuels are achieving considerable production cost advantages compared to HVO's from 2020 onwards.

The HPO process is more modular compared to the FT process but also pyrolysis requires a significant upfront capital investment. However, investment cost will be lower on a capital/ton basis than FT as it is expected that the upgrading of pyrolysis oils will use existing refinery infrastructure and stand alone HPO production is unlikely to be realized.

All of the available technologies for aviation biofuel production have substantially different but long term potentially viable business models.

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.

Significant reduction of the FT biofuel conversion costs component are expected to materialize based on cost optimized processes from 2020 onwards. Especially industrial "first-of-its-kind" FT equipped biomass gasification plants and HPO facilities are requiring considerable support to attract investors.

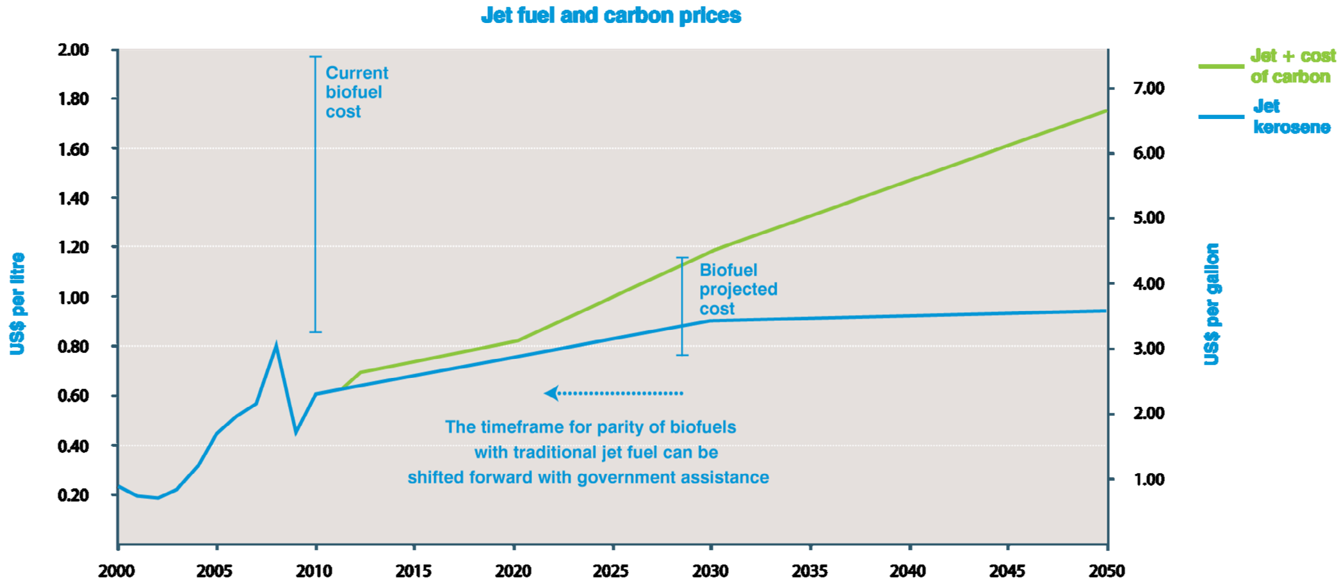
Long term biofuel off-take agreements at prices covering production cost besides offering a decent return on invested capital are a precondition to trigger investment decisions in biofuel production plants using lignocellulosic or waste biomass as feedstock materials due to relatively high specific investment cost.

In the case of diesel for road use, the difference between biodiesel and conventional diesel currently trades at the non-use penalty of 700 Euro/tonne. Taking this as the basis for the additional costs of aviation bio kerosene, the total surplus cost of 2 million tons of bio-kerosene would be estimated to be about 1.4 billion Euro. Thus, any intervention 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.

[28]For comparison, the price per ton of conventional kerosene was ca. 752 EUR/Tonne on 3 May 2011; HETCO Daily report 040511.

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 the extra fuel cost through to the passenger is only possible when a level playing field is achieved.

The current price of about € 16 for an allowance to emit one tonne of CO_2 would add 2-3% to jet kerosene prices, closing the gap with biofuel costs only marginally. However, the allowance prices will increase in the future and the cost of carbon is expected to double kerosene prices as indicated in the figure below, produced by the ATAG report (see footnote 27).



Source: Jet kerosene price based on 25% markup over IEA's crude oil forecast in Energy Technology perspectives 2010. Carbon price taken from UK DECC 2010 central case forecast for traded carbon price. All are in constant (inflation adjusted) US dollars. IATA Economics. Schematic, indicative diagram.

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. However, globally these fuels are existing only at large scale industrial demonstration and there are not any commercial plants to supply them on a regular basis. Although the optimisation of the various conversion processes has to be accelerated and significant efforts are still needed in new and emerging technologies (such as algal based biofuels, direct conversion of sugars to hydrocarbon et al) the technology foundations to convert biomass to high quality biofuels are available today.

However, there are three hurdles that at present make it impossible to deploy second generation biofuels commercially: the lack of policy incentives, the lack of adequate financial instruments in constructing the plants and the lack of long term off-take agreements between the biofuel producers and the aviation industry.

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 biofuels; it is left up to the market operators to use any biofuel as long as the sustainability criteria of the RED are met. On the contrary, there are no comparable incentives for using biofuels in aviation. In the aviation sector only high physical quality biofuels (e.g. those with low freezing point or high purity) can be used to ensure the operability of the jet engines. This has led to the 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.

European financial institutions have so far shied away from the financing of second generation biofuels in general and aviation biofuels in particular because they have been awaiting the implementation of the sustainability criteria, the technical risks associated with building a first-of-its-kind-plant, and lack of targeted policy and financial incentives. Venture capital in the EU is very timid and in any case the necessary capital to build such plants usually exceeds the capabilities of venture capitalists.

Finally the market for aviation biofuels is non-existent at present. Second generation biofuels will be more expensive than kerosene for the near term, the aviation industry pays its infrastructure costs by other means than taxes on fuel, and there is no advantage for aviation to use biofuels. On the contrary, their use necessitates extensive testing, strict quality specifications and detailed certification, all additional efforts in an industry that faces extensive global competition. From the biofuels producers point of view there are no biofuel off-take agreements with the aviation sector ensuring the sale of their more expensive fuel compared to kerosene. Therefore from one point of view the aviation industry is faced with a more expensive fuel that has to undergo significant integration activities in its traditional fuel supply system and from the other point of view the biofuel producers are faced with a huge investment cost and a lack of real demand.

In short: an industry in its infancy. The status of second generation biofuels is best compared to that of the offshore wind sector in the early 80ies.

Although sustainable resources and the supply of renewable hydrogen are not critical issues at present, the industry has to carefully develop strategies to address them for the long term. Especially new strategies are needed to ensure the supply of sustainable oils that could be used in hydrotreating processes. Renewable hydrogen for instance can be produced via the same biomass gasification process also used in syngas production for FT fuels.

Summary

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

There is policy at EU level for the production and use of biofuels, including in the aviation sector.

The EU can meet its RED biofuels targets with sustainable resources. Europe's lignocellulosic and HVO biofuel industries are technology global leaders and pose the know how to move to the deployment phase.

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. Certified biofuels present no technical or safety problem in flights.

B. WHERE WE NEED TO GO - AND HOW

To achieve a 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 will take place in two steps; first the starting of operation of the first of its kind dedicated plants by 2015 and then the second series plants should start construction by 2016 and operation by 2018.[29]

Policymakers should ensure that an appropriate policy and financial support framework for second generation biofuels is in place to reduce the risk of investment in commercial scale production plants.

By 2015 we need:

- A clear and effective communication strategy from the aviation industry towards the European passenger concerning the advantages of using sustainable biofuels without any compromise on safety.
- 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.
- Full development of quality standards, certified use of biofuels and on flight testing.
- Supply of sustainably produced vegetable or other natural oils and fats for at least one existing HVO plant and 2 new HVO plants.

[29] Note. HVO plants already exist in commercial scale.

- Construction of at least 3 biofuel production plants at commercial scale based on technologies which are enabling the utilization of lignocellulosic feedstock materials (2FT and 1HPO).[30]
- Mechanisms to create a real market for aviation biofuels through the implementation of appropriate policy and financial support instruments. For example encouraging member states to implement legislation facilitating the use of biofuels in aviation. Allocation of a part of the ETS revenues via tools such as the NER 300 (or similar) to support the continuous technology development and use of lignocellulosic biofuels from first-of-its-kind plants could substantially accelerate biomass based aviation fuel utilization.

Milestones: *Reliable supply chain for certified sustainable resources, conversion of HVO plants to produce aviation class biofuels and commissioning of 3 plants producing lignocellulosic based aviation biofuels.*

Costs: *1,300 M€*[31]

By 2018 we need:

- Commercial flights using bio-kerosene blends.
- Construction of the second series of 4 biofuel production plants at commercial scale, (2FT and 2 HPO)
- Construction of two algal oil producing plants.
- Supply of affordable algae and microbe oils to be used as the raw material for existing and new HVO plants.

Milestones: *Commissioning of 4 plants producing lignocellulosic based aviation biofuels and at least 2 HVO plants producing algae and microbe oil based biofuels.*

Costs: *1,700 M€*[32]

By 2020 we need:

- Commercialisation of the biofuel production technologies.
- Full deployment of at least 2 million tons biofuels per annum in aviation in the EU.
- If not all, several EU airports operate with biofuel blends.

Financing mechanisms

All lignocellulosic biofuel technologies are potentially commercially viable; however, the banking sector considers them as too risky and is reluctant to provide loans. The

[30] Further construction of HVO plants supplied with sustainable oils and fats could continue by the industry. These could be used in addition to supply biofuels for the aviation for supplying heavy duty road transport applications.

[31] Based on the following cost estimates: FT plant 500 M€, HPO plant 250 M€, and 50 M€ to modify HVO plants to produce aviation class biofuel.

[32] Based on the following cost estimates: FT plant 450 M€, HPO plant 200 M€, Algae farms prodcuing algal oils 200 M€.

key problem faced by the advanced biofuels industry today is to secure the funds under competitive conditions to build the production facilities. This problem applies across the sector and not only to biofuel technologies that address the aviation sector.

An excellent analysis of financing mechanisms under the framework of the SET Plan has been published recently by the Centre for European policy Studies titled "*The SET Plan: From Concept to Successful Implementation*"[33]; below are some extracts from this report that are pertinent to financial mechanisms.

- **The FP7 Risk Sharing Financial Facility (RSFF)** addressing bankable projects for which the credit risk is perceived to be low or sub-investment grade. The European Investment Bank and the European Commission launched the RSFF in 2007. The EIB and the Commission each provide €1 billion as a capital cushion to cover the risks incurred for the provision of debt financing of approximately €10 billion of loans under RSFF[33]. This facility provides substantial additional debt finance to compliment more conventional sources of finance such as grants, equity and loans. However, no advanced biofuels project has been successful in participating in the RSFF and there is need and scope for optimisation. Between now and the end of 2013, the Commission and the EIB Group will expand the scope and scale of the existing RSFF, taking into account lessons learnt so far. It is considered to putting in place a "renewed RSFF for the period 2014-2020 with a budget of €5 billion.
  An instrument like the RSFF dedicated to energy could be developed. Such a debt or loan guarantee instrument is used successfully in the US, whose Department of Energy has a dedicated financial instrument for energy technologies. RSFF is also attractive to the private sector because they are exempt from the stringent nature of FP7 agreements and in particular from the IPRobligations.

- The expansion of loan guarantee instruments can be complemented with **EU project bonds** for specific late stage more mature long-term projects. These have been proposed in the Europe 2020 strategy by the European Commission. More precisely the aim is to recourse to bonds for the financing of projects as one financial instrument to address the funding needs of major infrastructure projects, with the bonds being issued by project companies. The objective of this approach is to attract additional private sector financing for individual infrastructure projects via a mechanism for enhancing the credit rating of bonds issued by a project company. Leveraging on existing EU funds, it is designed to act as a catalyst to re-open the debt capital market (currently largely untapped for infrastructure investments following the financial crisis) as a significant source of financing in the infrastructure sector. However, project bonds do not need to be limited to infrastructures; they could also be considered for pan-European demonstration and deployment projects for new energy technologies when the costs are high and timeframes long. An example of bonds which can potentially be used for deployment of technologies is the

[33] The SET Plan: From Concept to Successful Implementation, CEPS Task Forcer Report, L.R. Liljelund et al., Centre for European policy Studies, Brussels, 2011.

EIB's "climate awareness bond", which is focused on investments in climate protection which includes, forexample, deployment of renewables.

- A major new source of financial support for renewables at the EU level – though outside the EU budget – is the so-called **NER 300 programme**, established under Article 10a(8) of the Emissions Trading Directive 2003/87/EC. NER300 is a funding programme for the demonstration of low-carbon technologies at commercial scale and aims to co-fund at least 34 innovative renewable energy technology demonstration projects in the territories of the EU member states, together with at least eight CCS demonstration projects. At current prices of EU ETS allowances, the programme will provide around €4.5 billion of co-funding, and will leverage a matching funding from industry and member states of the same magnitude[34]. The Commission launched the first Call for Proposals comprising 200 million allowances under the NER300 programme in November 2010, the award decision is expected in the second half of 2012[35]. The NER300 funding raised by the Commission via issuing ETS allowances certificates is expected to be supplemented by MS contributions subject to state aid assessment and clearance by the Commission of the public funding contribution. Projects benefiting from NER300 support could raise additional funding from other sources (e.g. commercial loans, EIB loans). The investment value of projects supported through the proceeds of the NER300 programme is expected to be a multiple of the equivalent allowances depending on the actual sales price of the certificate and on the true perimeter of the relevant cost identified in the regulation. The NER300 process is planned to last until 2013 but the actual implementation period might be longer, depending on factors such as the type of projects funded, potential administrative and operational delays for the completion of the project.

- The European Commission (2010b) has recently proposed the creation of an"**Innovation/Technology Accelerator**" under the EU ETS. This new mechanism would support early investors in top performing low-carbon technologies by rewarding them with additional free allowances, i.e. a potentially similar structure as the NER 300 in terms of governance *but* not in the Directive. It is worth noting that this could be a deviation from the present aim to keep a technology-neutral approach, avoiding picking winners. The primary aim is to strengthen the reward for fast movers, i.e. benefits beyond the carbon price effect. Such a mechanism could work through the benchmarking system of allocating free allowances to industry sectors and would have to rely on surplus allowances left over within the maximum available amount, i.e. once the allocation is complete. These extra allowances would then help finance the investments by companies that commit to out-perform the relevant sector benchmark or to make rapid advances towards it, such as by improving carbon intensity. Whether the innovation/technology

[34] See Commission Decision 2010/670/EU of 6.11.2010, OJ L 290, p. 39.

[35] OJ C 302, 9.11.2010, p. 4, further information is available at: http://ec.europa.eu/clima/funding/ner300/index_en.htm

accelerator is ultimately introduced and what its operational details will be is still a matter of discussion.

- Interested Member States should provide **loan guarantees** for biofuel plants built in their territory supplying their major airports and airlines with biofuels. EU State Aid rules have to be considered. For comparison the US Department of Energy's loan guarantee program aims to accelerate the commercial deployment of technologies that reduce emissions of GHG and employ new or significantly improved technologies and has so far committed close to $18 billion to support 20 clean energy projects including biofuels. The US Department of Energy has requested the US Congress to provide funding to support more than $40 billion in additional future projects[33].

- Other fiscal mechanisms to de-risk ongoing investment in renewable energy.

Summary

To deploy 2M tonnes of aviation biofuels in the EU by 2020 we need:

- *Widely available supply of sustainably produced oils.*
- *9 plants with advanced technologies producing biofuels from lignocellulosic biomass, agricultural residues and waste streams.*
- *3,000 M€*

Innovative financing for such first-of –a-kind plants:

-*Make RSFF an effective tool under the new debt instrument by 2014*
-*Member States' loan guarantees for the operators of the plants.*
-*Other fiscal measurements such as low interest rates and equity capital.*

C. A POSSIBLE FLIGHTPATH

There are three existing operational HVO plants and the fourth under construction in Rotterdam that could be modified by minor investments to continuously convert roughly 60% of the processed vegetable oil to renewable aviation fuel as their main product[36]. At this stage the volume of renewable aviation fuel is limited by the availability of such sustainably produced oils and fats that are acceptable for all consumers. Various industry initiatives exist aiming to provide sustainably produced plant oils from new sources. It is yet unclear at which commercial conditions future large scale supply of e.g. jatropha oils can be realized from degraded land due to much lower yields than previously expected. A competing HVO technology could provide 2 plants of 300 kt HVO using sustainably produced vegetable oils contributing another 600 kt. These plants do not need financial support since the technology is considered commercial. However some incentives will be needed if these existing plants shall be encouraged to modify operation towards aviation biofuels production (see footnote 11).

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

One Choren-type biomass gasification plant equipped with FT synthesis may be built by 2015 this will provide 200,000 t/a FT product. A second plant can be expected to start operation by 2018 providing another 200,000 t/a FT and a total of 400,000 t/a FT by 2020. Roughly 70% of FT product can be upgraded to the required kerosene quality demanded by the aviation industry, resulting in 280,000 t/a kerosene from the above defined production capacity. The remaining FT fractions can be supplied e.g. to the road transport sector.

One or two competing gasification/FT consortia could be able to construct 2 more FT plants of 50-150,000 t/a FT product capacity per plant over the same periods of time, thus contributing in total about 300,000 t/a by 2020.

Specifically for HPO the target is to achieve a 100,000 t/a production capacity in 2020 increasing to 400,000 t/a in 2025. Currently, the first pyrolysis oil production plants are to be built in Europe. The first quantities of crude pyrolysis oil from these production facilities can be expected in 2012. Initially the total volume will be about 20-50,000 t/a increasing to targeted 1,000,000 t/a in 2020. Part of the production volume can be made available for aviation fuels, e.g. 25% or 250,000 t/a. It is targeted to convert this amount of pyrolysis oil into a 100,000 t/a of jet A-1 compatible aviation fuel.

It is envisaged that algal oils will enter the biofuels markets by 2018 and that 2 plants will be built with 80,000 t/a biofuel annual capacity by 2020. This will make a further contribution of about 160,000 t/a.

The table below shows the key technology providers and possible 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-Netherlands	HVO	800,000	0	2011
Neste-Singapore	HVO	800,000	0	2010
Neste-Finland 1	HVO	190,000	0	2007
Neste-Finland 2	HVO	190,000	0	2009
UOP-Italy	HVO		0	
UOP-Spain	HVO		0	
Choren-Germany	FT		0	
BTG-Netherlands	PO	1,000,000	50-100,000 t/a HPO	
Evergent Techn.-??	HPO		0	
Neste/Stora Enso-Finland	FT		0	
Solena-UK	FT		0	2015
UPM/Carbona - Finland	FT		0	
CEA - France	FT		0	
Aqualia - Spain	Algal oils		0	
Abengoa - Spain	Algal oils		0	

If all the above plants were built, significant quantities of advanced biofuels would become available by 2020, however, it is expected that not all of these plants will materialise and that even if they materialise not all of them will produce aviation quality biofuels. Nevertheless the industry is confident that given the right policy and financing conditions 2,000,000 t/a of biofuels can be sustainably produced for aviation. This would satisfy the target of 1% replacement of kerosene for global aviation by 2020.

Annex: Advanced Biofuel Technologies

Hydrogenated Vegetable oils

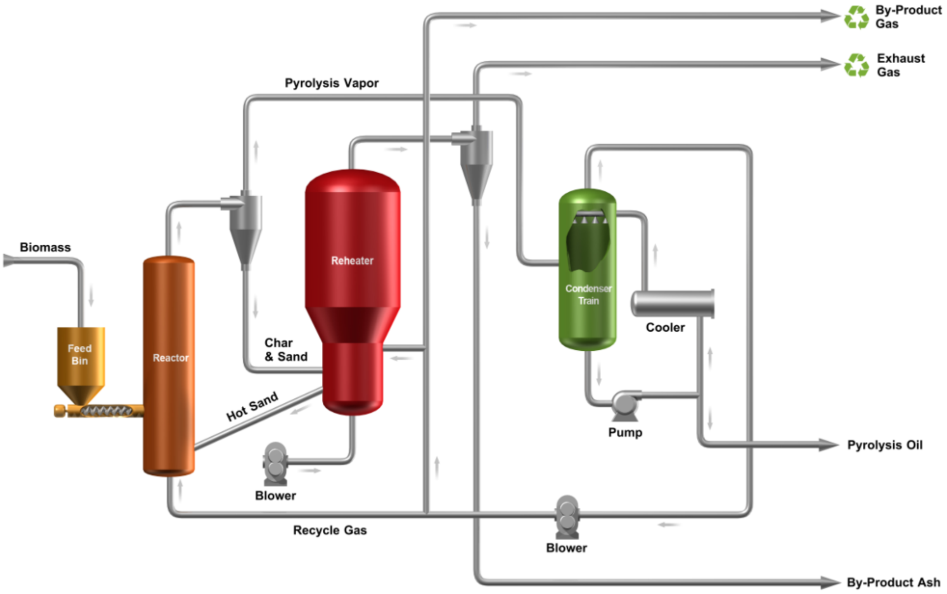
HVO have been commercialised by NESTE of Finland. The technology is feedstock-flexible and can use a variable mix of different vegetable oils and animal fats as its raw material, including algae and microbial oils. The current main feedstocks for HVO production are palm oil and animal fat. In order to be able to supply aviation sector with biofuels, these feedstock shall have to be certified to meet the RED sustainability criteria.

UOP, a Honeywell Company, has also commercialised a feedstock-flexible HVO technology, both for the production of green diesel and green jet fuel. Several projects have been announced globally. In the EU projects have been announced for the production of green diesel with ENI and Galp Energia, though neither project has yet started construction. Others projects could be directed towards the production of HVO aviation biofuel if incentives are in place.

Hydrogenated Pyrolysis Oils

HPO is under development by Envergent Technologies; a joint venture between UOP and Ensyn Corporation of Canada. The figures below show the simplified process flowsheet of the Rapid Thermal Pyrolysis of Envergent Technologies and a photo of the process development unit. The consortium is targeting to develop/demonstrate/implement a pyrolysis oil upgrading process, initially via a demo plant at the Tesoro refinery in Hawaii. Envergent Technologies has announced a number of commercial projects for the production of crude pyrolysis oil in Europe.

Initially these projects will use sustainable biomass to make pyrolysis oil for the production of green heat or green electricity, though once the upgrading technology is developed these facilities could be modified to add upgrading plants or they could send pyrolysis oil to a central upgrading facility to produce HPO.



Courtesy UOP/ Envergent Technologies

The Biomass Technology Group (BTG) of the Netherlands has a similar technology to that of Ensyn and has been involved in co-refining in existing oil refineries. (Note: BTG is supported by the EC under FP7 with the EMPYRO project to demonstrate pyrolysis oil production; see an artist's schematic in below). In Europe also a large project called ‘Biocoup’’ (www.biocoup.eu) is nearly completed to convert crude pyrolysis oil into a refinery compatible feedstock (e.g. co-feeding Fluidized bed Catalytic Cracker, hydrotreater or even crude oil distillation). The advantage here is that optimal use being made of existing refining infrastructure and capacity. Furthermore, it is realized that even after hydrotreating the upgraded pyrolysis oil will still contain a broad range of different components, and as such probably it may not comply with a single specific fuel specifications. However, at a refinery an optimal distribution of the upgraded oil over different products can be achieved. On small scale it has been demonstrated that 20% of mineral VGO (Vacuum Gas Oil) can be replaced by HPO.

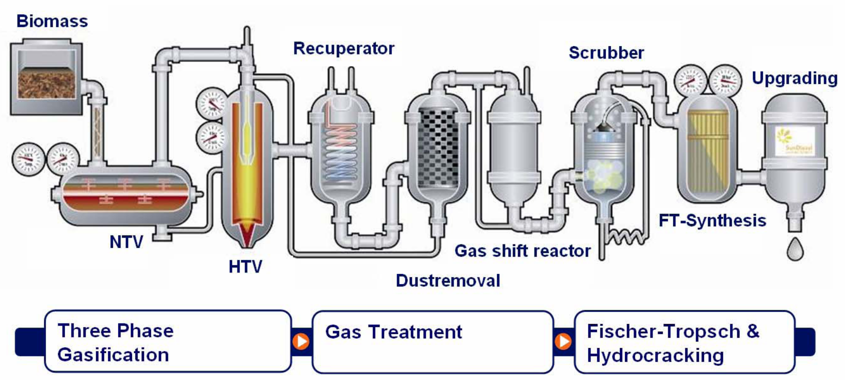
The upgrading of crude pyrolysis oil into a product which is compatible or can be blended with conventional jet fuel has not yet been demonstrated on a reasonable scale (for example a few hundred kg of product/day).

There are other industrial groups that are well advanced on pyrolysis oils such as Bioliq based in Germany (focussing on pyrolysis oil gasification), Pytec (Germany), and UPM/VTT in Finland. BioLiq is producing a slurry consisting of pyrolysis oil and char, and can not be used for the production of HPO, but possibly suitable for FT.

Courtesy of BTG

Fischer-Tropsch

FT biofuel production is under development by CHOREN Industries (Germany). CHOREN is in the commissioning phase of a ~ 13.000 t/a demonstration plant and is expecting to produce first fuel by end of 2011. Parallel CHOREN is up-scaling its gasification technology to industrial scale. (Note: Choren is supported by the EC under FP7 with the OPTFUEL project). The photo below shows the Choren demonstration plant at Freiburg, Germany and the following figure a simplified process schematic.



Courtesy Choren

There are other industrial groups that are well advanced on FT biofuels such as the UPM and Carbona joint venture and the Neste Oil & Stora Enso joint venture in Finland and the Solena project in the UK.

Algae based biofuels

The recent iinterest in algae is due to reports of very high oil yields and dramatic greenhouse gas (GHG) savings, all devoid of any negative effect on farming. But an in-depth analysis of algae reveals that their potential is not limitless and that further research and optimisation is needed in order to maximize the benefits drawn from and minimize the environmental impacts caused by algae.

Aquatic microalgae are among the fastest growing photosynthetic organisms. They have carbon fixation rates in an order of magnitude higher than those of land grown plants and can be continually harvested, with harvesting cycles ranging between one and ten days. They produce oils that can be converted into aviation fuels via HVO while the biomass residue can be used for further energy production (in combined heat and power applications or synthetic biofuels via gasification and pyrolysis).

Although commercial applications for algae exist for certain niche markets, only the last few years attention has been paid to biofuels. Several large scale demonstration projects are being implemented globally and especially in the US and the EU (see Table 2)[37]. However, algal based biofuels are still about 6-8 years from the commercial deployment stage.

[37] "Algal Biofuels Developments in the EU", L. Hobson, N.L. Lopez, K. Maniatis, M. Soares Pinto, F. Rogalla, in Fuel, Hart Energy publication, March 2011