Biofuels for Aviation: Review and analysis of options for market development

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<th>Acronym</th>
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<tr>
<td>ACARE</td>
<td>Advisory Council for Aviation Research and Innovation in Europe</td>
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<td>AFTF</td>
<td>Alternative Fuels Task Force (ICAO)</td>
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<td>ANSP</td>
<td>Air Navigation Services Provider</td>
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<td>ASTM</td>
<td>American Society of the International Association for Testing and Materials</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>CDM</td>
<td>Clean Development Mechanism</td>
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<td>CER</td>
<td>Certified Emission Reductions</td>
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<td>CRCO</td>
<td>Central Route Charges Office</td>
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<td>EU</td>
<td>ETS European Union Emission Trading Scheme</td>
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<td>FAME</td>
<td>Fatty acid methyl esters</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>FQD</td>
<td>Fuel Quality Directive</td>
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<td>FT</td>
<td>Fischer-Tropsch</td>
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<td>HEFA</td>
<td>Hydro-processed esters and fatty acids</td>
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<td>IATA</td>
<td>International Air Transport Association</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>ICCT</td>
<td>International Council on Clean Transportation</td>
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<td>ILUC</td>
<td>Indirect Land Use Change</td>
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<td>JI</td>
<td>Joint Implementation</td>
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<td>MBM</td>
<td>Market-based measures</td>
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<td>MTOW</td>
<td>Maximum Take Off Weight</td>
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<td>RED</td>
<td>Renewable Energy Directive</td>
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<td>RFS</td>
<td>Renewable Fuel Standards</td>
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<td>RINs</td>
<td>Renewable Identification Numbers</td>
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<td>RVO</td>
<td>Recovered Waste Vegetable Oil</td>
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<td>SIP</td>
<td>Synthetic Iso-paraffin</td>
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<tr>
<td>SU</td>
<td>Service Units</td>
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<td>TSU</td>
<td>Total Service Units</td>
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<td>WEO</td>
<td>World Energy Outlook</td>
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<td>WTP</td>
<td>Willingness to pay</td>
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**EXECUTIVE SUMMARY**

This report\(^1\) investigates, at a high level, a number of possible mechanisms to stimulate the growth of a biojet fuel industry in Europe, to deliver and assist the aviation industry in meaningful emissions reduction in the future. Like any new technology or industry, challenges and barriers to market development exist. For biojet fuel, these are primarily economic insofar as the cost of producing biojet fuel is more expensive than today's market cost of jet kerosene, thus remaining an unattractive option for large-scale uptake by the industry. The objective of this report is to review frameworks where the current cost differential between jet kerosene and biojet fuel can be recovered and redistributed to suppliers in an efficient and fair manner, to assist the development of the industry, introduce scale to the industry and reduce the cost of biojet fuel in the medium to long term.

In most areas of transport, emission reductions (as measured by marginal abatement cost) are generally expensive. To date surface transport in the EU has benefited from the push effect of renewable transport energy policy\(^1\). This has led to the development of a biodiesel industry in the EU to meet the demand created by renewable fuel obligations. Biojet fuel has not benefited from this uplift with only one Member State (Netherlands) acknowledging the option of biojet fuel as a mean of contribution to the renewable transport target.

The International Civil Aviation Organization (ICAO) has been exploring policy options to limit or reduce the greenhouse gas emissions from civil aviation, particularly in response to Assembly Resolution A32-8 since as early as 2001. Acknowledging the policy latency in this area to date and the challenge in implementing a global market based mechanism by 2020, it is important for the integrity of the aviation industry, given stated commitments to emission reduction, that contingency options are available to deliver long-term meaningful reductions. It is widely accepted by stakeholders in the aviation industry that biojet fuel will be an integral part of the medium to longer-term pathway to decarbonisation. In the near to short term, biojet fuels are expected to remain expensive.

We explore the option of cost recovery of biojet fuel through the modulation of en-route charges and find that while the existing framework is an attractive option, there are a number of key challenges, which may make it unsuitable. These challenges include the operationalization and implementation of the scheme within a suitable timeframe; uncertainty of how such a scheme would integrate with the existing EU ETS and forthcoming ICAO market based proposal, and the potential for reputational risk to the existing route charging scheme should the issue be politicised.

We conclude that other support mechanisms include existing mechanisms such as the Renewable Energy Directive should be explored to assess their suitability for stimulation of a biojet fuel industry in Europe.

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+ In this report, there is a need to differentiate between the objective to reduce greenhouse gas (GHG) emissions at low marginal abatement cost and the objective to stimulate a biojet fuel industry in Europe.
I. INTRODUCTION

Aviation is one of the strongest growing transport sectors globally. Airline operations produced 705 million metric tonnes (Mt) of CO₂ in 2013, just under 2% of total man-made CO₂ emissions. This is approximately equivalent to global emissions from energy-intensive industries such as cement production and refineries and is higher than the total annual 2013 CO₂ emissions of all EU Member States except Germany. In light of discussions at COP21 in Paris last year, it is internationally recognised that all sectors, including aviation, must contribute to greenhouse gas emission reduction efforts in order to keep the global temperature increase well below 2°C compared to pre-industrial levels.

In the period up to 2050, worldwide aviation is expected to grow by up to 5% annually. If fuel consumption and CO₂ emissions were to grow at the same rate, CO₂ emissions by global aviation in 2050 would be more than six times the current figure. Global passenger traffic (annual passengers transported) increased from around one billion passengers in 1990 to more than three billion passenger’s today. Since 1970, global air traffic has doubled every 15 years, a trend which is expected to continue.

On an average day, over 26,800 flights pass over European airspace and with just 7% of the world’s population, these flights accounts for around 25% of global air traffic. Europe is home to approximately 3,800 passenger aircraft and over 700 large commercial airports which supported the movement of 879 million passengers in 2014 (as reported by Eurostat). Following the economic crisis, a significant recovery in the aviation industry was seen in 2014, with a 4% increase in passenger numbers from 2013. CO₂ emissions from aviation in 2012 in Europe were 150 Mt, representing 12.8% of total transport emissions or 3% of EU 28 emissions. Final energy consumption in aviation 2013 was 49 Mtoe, 14% of transport energy usage or 4% of final energy consumption across all EU 28 sectors.

There are a number of Global and European targets for emissions reduction and alternative fuel use in aviation. The Advisory Council for Aviation Research and Innovation in Europe (ACARE) have a GHG emissions target of a 50% reduction in CO₂ per passenger kilometre by 2020 (relative to 2000 levels) and a 75% reduction by 2050. These carbon-intensity targets are therefore independent of traffic growth. The International Air Transport Association (IATA) has also set ambitious targets to curb fuel consumption and mitigate emissions from aviation in its Carbon Neutral Growth (CNG) initiative, under which the aviation industry has committed to an average improvement in fuel efficiency of 1.5% per year from 2010 to 2020 and a cap on aviation CO₂ emissions growth from 2020 (carbon-neutral growth). By 2050, the ambition is to reduce CO₂ emissions from aviation by 50% relative to 2005 levels.

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2 Aviation’s impacts via O3 (ozone) and contrails occur predominantly in northern mid-latitudes and the upper troposphere, leading potentially to climate change of a different nature than that from CO₂ (IPCC).
5 With more than 15,000 passenger movements per year
Box 1: Impact of aviation on global warming

As outlined in an EU report by the Directorate General for Internal Policies replacing fossil fuels with biojet fuels with less GHG emissions does not eliminate the entire negative impact of aviation on global warming. If non-CO₂ combustion effects from aircraft in the upper atmosphere are taken into account, the relative merit of a fuel with zero life cycle GHG emissions would entail a 100% reduction in GHG emissions - but reduce the actual climate impact by only 48% when estimated in a 100-year time window. This means “that methods of tracking climate change mitigation that rely exclusively on relative well-to-wake life cycle GHG emissions as a proxy for aviation climate impact may overestimate the impact of alternative fuel use on the global climate system”. It is important to note that the level of scientific understanding in this area is currently low.

In Europe, the political and regulatory landscape for biofuels is under transition. The revision of the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) aim to accelerate the transition from the first generation biofuels and other renewables options in transport as well as account for the effects of Indirect Land Use Change (ILUC). A number of targets and policy instruments exist that concern biofuels including biojet fuels. The EU’s Renewable Energy Directive (Directive 2009/28/EC) sets a binding target of 20% gross energy consumption from renewable sources by 2020 (20% RES). Each Member State is also required to have at least 10% of their (land-based) transport fuels from renewable sources (10% RES-T) by 2020. It is anticipated that liquid biofuels in road transport will make a significant contribution to the 10% RES-T target. In the case of both targets, only biofuels that meet specific sustainability criteria can be included. To support aviation specifically, the Biofuel FlightPath Initiative was introduced in June 2011. The European Commission with Airbus, Air-France-KLM, British Airways, Lufthansa and biofuel producers Chemtex Italia, Neste Oil, Biomass Technology Group, UOP and UPM are targeting 2 Mt annual production of fuel derived from renewable sources by 2020. This equates to approximately 1% of the total global jet fuel consumption in 2020 or 4% of EU jet fuel consumption. To put this in context, in 2013 approximately 13.1 Mt of biofuels were consumed in all forms of transport in Europe.

Biojet fuel is currently expensive and is projected to remain so relative to jet kerosene, as illustrated by Figure 1. Producing biojet fuels for aviation is more costly than for road transportation because aviation’s requirement for “drop-in” fuels calls for more advanced processes than those deployed for the first generation of road transportation biofuels (e.g. ethanol and FAME) and for further upgrading of the fuel in order to meet jet fuel specifications. Biojet fuels are currently produced in small quantities compared to both jet kerosene, and can cost orders of magnitude higher than today’s market cost of jet kerosene, thus remaining an unattractive option for large-scale uptake by the industry.

While there are no specific figures for Europe in terms of volumes consumed, over 200 flights were operated globally in 2014 using alternative jet fuel. In a previous report, an overview of the state of the art in biojet fuels was presented with high-level figures on costs and provides complimentary reading to the more detailed review in this study.

### 1.1. Scope

The objective of this report is to review and analyse options for biojet market development in Europe to meet the Biofuel FlightPath target. An assessment of these options cannot be divorced from existing EU bioenergy policy; therefore, a review of current use and bioenergy policy in the EU is presented. Areas of complementarity and conflict are highlighted and in particular, policy recommendations are made to ensure cohesiveness in the overall renewable energy policy landscape. A review of existing methods and pathways to create biojet fuel is presented as this provides an important base not only for an understanding of the type and quantity of feedstocks required but also for implications for sustainability and potential emissions reduction. The report then reviews existing and proposed mechanisms that may be exploited to bring higher levels of biojet fuels to market.

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II. AVIATION IN THE EU

Aviation is a strategically important sector that makes a vital contribution to the EU’s overall economy and employment, supports 5.1 million jobs and contributes €365 billion, or 2.4% to European GDP\(^9\). In December 2015 the European Commission adopted an Aviation Strategy for Europe\(^10\), with the stated goal to boost Europe’s economy, strengthen its industrial base and reinforce its global leadership position. The strategy recognises that the future competitiveness of European aviation and its environmental sustainability go hand-in-hand and that the role of biofuels can play in emission reduction, job creation and competitiveness for the aviation industry. Interestingly from the public consultation for the strategy, stakeholders were asked about the preferred options to reduce the carbon footprint in aviation. EU citizens suggested to focus on 1) improved aircraft design, 2) fuel taxation in aviation, 3) ATM solutions. Asked the same question, aviation professionals showed a clear preference for industry-led initiatives. Innovation meaning more use of biofuels, improved aircraft design and above all more direct flights and other ATM solutions were equally important and to be preferred to solutions such as passenger charges based on the ‘polluter pays principle’ or fuel taxation in aviation.

In the EU, low-fare airlines are now amongst the top carriers both in terms of passengers and in terms of market capitalisation. In 2015, they accounted for 48% of seat capacity\(^9\). The EU Member State with most airline groups in 2014 was the UK (8 groups), followed by Germany and France (3 each), Italy, Ireland, Luxembourg, Spain and Sweden (2 each), and Portugal, Denmark, Finland, Belgium, Greece, Hungary, Czech Republic and Poland (1 each). Current reported net profit margins of leading EU airline groups are between -0.8% (Air France) and 15.3% (Ryanair), with Lufthansa reporting a margin of 0.2%, IAG (British Airways) 5.0% and Easyjet 9.9%\(^9\).

European citizens on average take 1.2 trip per year\(^11\) compared to 1.6 trips per year for North American travellers. Figure 2 shows passenger movements between EU Member States in 2014.

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\(^10\) EC Aviation Strategy for Europe website, ec.europa.eu/transport/modes/air/aviation-strategy/index_en.htm

Flights from UK to Spain and visa versa are the most common route, reflecting in some part Spain’s popularity as a holiday destination. The top-ranking regions in terms of the number of air passengers tended to be capital regions in western EU Member States, in other words, those regions in which the EU’s largest airports were located. These relatively large airports often serve as hubs for intercontinental air traffic and this is especially true for London-Heathrow, Paris-Charles de Gaulle, Frankfurt airport and Amsterdam-Schiphol.
III. BIOENERGY POLICY AND USE IN THE EU

Bioenergy policy in the EU has been one of the most volatile energy policy areas to date. Uncertainty in regulation has been a contributing factor to the slow progress toward the RES-T target. Successful development of biojet fuel use in Europe will require strong and clear policy that is consistent and complimentary to existing policies and frameworks. The recent high profile cancelling of the British Airways biojet fuel plant in the UK and bankruptcy of Solena Fuels in the USA points to the difficulties and challenges of this newly developing industry.

III.A. EU bioenergy policy

The EU’s Renewable Energy Directive sets a binding target of 20% gross final energy consumption from renewable sources by 2020 (20% RES). To achieve this, the Directive allocates individual targets to Member States ranging from 10% in Malta to 49% in Sweden. Each Member State is also required to have at least 10% of their transport fuels from renewable sources by 2020 [recent revisions to the RED are discussed below]. It is anticipated that liquid biofuels in road transport will make the largest contribution to the 10% RES-T target owing to the fact that road transport accounts for approximately 72% of transport emissions. Electric vehicles also contribute to the target but their contribution is expected to be small. In the case of both targets, only biofuels that meet specific sustainability criteria can be included.

For the RES-T 10% target, the ratio determining a Member State’s RES-T share is defined in the Article 3(4) of the RES Directive. This Article defines both the numerator and the denominator. For the denominator petrol, diesel, biofuels consumed in road and rail transport, and electricity is taken into account. While aviation gasoline is allowed for in the denominator, aviation kerosene is not. However, the numerator ‘energy from renewable sources consumed in transport’ does allow for biofuels and synthetic fuels of renewable origin in all modes of transport once they are compliant with sustainable criteria. Therefore, in principle, biojet fuel usage can count towards the 10% RES-T target.

The denominator for the 20% RES target includes energy use in aviation, while the numerator includes all forms of renewable energy in all forms of transport. Therefore, in principle, biojet fuel usage can also count towards the 20% RES target. The current contribution of biojet fuel to meet the RED target is virtually zero. The Netherlands is the only country to have actively implemented the provision for biojet fuel to count towards the RED target in their national legislation.

The Fuel Quality Directive (Directive 2009/30/EC) is a parallel policy to the RED and sets a target for European transport fuel suppliers to reduce the lifecycle carbon intensity of their fuel by at least 6% by the end of 2020 relative to a 2010 baseline. Currently the FQD applies to road and non-road mobile machinery and not to aviation but recent proposed revisions of the RED may allow an option to change this. This is discussed later in the report.

12 BA blames UK government for scrapping of £340m green fuels project. Guardian website - www.theguardian.com/environment/2016/jan/06/ba-blames-uk-government-for-scrapping-of-340m-green-fuels-project
13 When calculating the amount of transport fuels to be reported, Directive 2009/28/EC defines which calorific values are to be used for transport fuels in Annex III. Biojet kerosene has a default value of 36.8 MJ/kg
14 Note: aviation gasoline is not to be confused with jet fuels (gasoline/kerosene-type jet fuels).
Progress on the 10% RES-T target has been challenging, reaching a 5.7% share in 2014 with a number of Member States expected not to meet their RES-T targets\textsuperscript{15}. The feasibility of the RES-T target has also been discussed at EU level\textsuperscript{16}. Part of the reason for slow progress was political uncertainty and discussions around the environmental effectiveness of certain biofuel pathways when emissions from indirect land use change are taken into account. Uncertainty of the European market, due to failure of the European Council to reach an agreement on biofuels regulations, created a barrier for the advancement of biofuels. While the production of biofuels was originally strongly encouraged by the Commission, current debates at European and national level rather discuss their limitation\textsuperscript{17}. This lack of consistency is all the more critical since investors of first generation biofuels are the same as those of second generation types. Investors who experienced negative consequences from the unstable support policy for first generation biofuels may be more reluctant to invest in second generation biofuels, including biojet fuels particularly if they compete with current investments.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Compliant Biofuels (liquid + gaseous) in Renewable Transport-EU 28 with possible trajectory to 2020. Trajectory to 2020 assumes 2014 penetration levels (%) of compliant biofuel.}
\end{figure}

In April 2015, the European Parliament approved the reform of the Renewable Energy Directive, which includes a 7% cap on food crop-based biofuels for the transport sector and only included


\textsuperscript{17} EurObserv-ER Biofuels barometer 2015. www.euroobserv-er.org/category/all-biofuels-barometers/
indirect land use change factors for reporting purposes. The Council has to confirm the Parliament’s vote. When approved, Member States will have to enact the new legislation by 2017. Other elements of the reform include:

- Member States should have an indicative target of 0.5% for advance biofuels. Member States will be allowed to set a lower target, based on objective reasons;
- New Annex IX of the RED contains feedstock for advanced biofuel that count double towards the targets;
- A multiplication factor of 5 for electricity from renewable sources in electric road vehicles and of 2.5 for electrified rail transport was introduced;
- ILUC reporting on GHG savings from the use of biofuels will be carried out by the EC. For that purpose, provisional estimated ILUC factors are included in new Annexes to the RED and FQD. The Council did not include binding sub-targets for advanced biofuels and fuel ethanol, which were supported by the Parliament.
- In the case of suppliers of biofuels for use in aviation, Member States may permit such suppliers to choose to become contributors to the reduction obligation laid down in Fuel Quality Directive to the extent that the biofuels supplied satisfy the sustainability criteria.

III.B. Biofuel consumption in the EU

Total biofuel consumption in the EU was at 14 Mtoe in 2014, with 12.5 Mtoe certified as sustainable according to EurObserv’ER, 2014 report\textsuperscript{18}. Currently, almost 80% of biofuel is biodiesel used in road transport. Biojet fuel for aviation is not explicitly accounted for in EU statistics; ‘other biofuels’ which would include biojet fuel, accounts for a small fraction (<1%) of total consumption. The use of renewable energy in 2013 resulted in 388 Mt of gross avoided CO\textsubscript{2} emissions at EU level\textsuperscript{19} and in 2012 Member States reported direct savings, (therefore not including emissions from indirect land use change), in emissions resulting from the use of renewable energy in transport of 34 Mt CO\textsubscript{2}-equivalent\textsuperscript{20}. However amendments to the RED point out that based on forecasts of biofuel demand provided by the Member States and estimates of indirect land-use change emissions for different biofuel feedstocks, it is likely that greenhouse gas emissions linked to indirect land-use change are significant, and could negate some or all of the greenhouse gas emission savings of individual biofuels. This is because almost the entire biofuel production in 2020 is expected to come from crops grown on land that could be used to satisfy food and feed markets.

\textsuperscript{18} Biofuels barometer 2015: www.eurobserv-er.org/category/all-biofuels-barometers/
\textsuperscript{19} Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions Renewable energy progress report. COM(2015) 293 final. https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-293-EN-F1-1.PDF
\textsuperscript{20} COMMISSION STAFF WORKING DOCUMENT Technical assessment of the EU biofuel sustainability and feasibility of 10% renewable energy target in transport. eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0117&rid=2
The largest consumer markets for current biofuels are France and Germany, accounting for 20% each, or 40% in total. Italy and the UK follow, accounting for approximately 16% of the market (Figure 4).

![Figure 4: Biofuel Consumption for transport by type for 2013 in the EU](image)

As illustrated in Figure 5 the majority of biofuels are produced in the EU. Domestic biodiesel production accounted for 79% of the total consumption in the EU, while imports came primarily from Argentina or Indonesia.

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Figure 5: Biofuel consumption, split between production and imports of biofuels in the EU, 2010-2012 (Source: Ecofys 2014)\textsuperscript{22}

EU Member States produced 71% of the ethanol consumed, with the imported share primarily from either the United States or Brazil. While food security in Africa has been raised as a concern in the context of biofuel consumption, with the exception of marginal bioethanol imports from Sudan, hardly any EU consumed biofuels were imported from Africa until 2013 and biofuel exports from Africa are only expected to show moderate growth in the future.

In addition to the importation of biofuels as a final product, some biofuel production is also carried out using imported feedstock. Ethanol feedstocks have a larger share originating from the EU, at a share of almost 80%. Wheat, maize and sugar beet are the main feedstocks, with around 20% of the maize sourced from the USA. For current biofuel production in Europe, the feedstocks and their source are shown in Figure 6.

Where feedstock is sourced from waste or agricultural residues, it implies zero land use change and substantial advantages over fossil fuel energy in terms of both greenhouse gas emission levels and ecosystem impacts. In recent years, the use of used cooking oil (RVO) has increased, particularly because biodiesel from this counts double in the schemes of several Member States. The blending of non-food based ethanol and biodiesel is estimated at about 0.6%, and thus already surpassing the non-binding target of 0.5% for second generation biofuels by 2020.

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22 Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions (2015). https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-293-EN-F1-1.PDF
sustainability of biofuels is assessed against the sustainability requirements contained in the Renewable Energy Directive. This and its relevance to biojet fuel is discussed in section III.C.

In terms of current biodiesel production capacity, the sector is dominated by German and French producers, who account for around 4.5 million tonnes. Neste Oil (Finland) and Biopetrol industries (Switzerland) account for an equal share of just over 2 million tonnes. For bio-ethanol, again France (Tereos, Cristanol) and Germany (CropEnergies, Verbio) dominate, with other big producers being Abengoa Bioenergy in Spain.

Production of bioenergy generally requires land unless using wastes or residues. Based on data about biofuels consumption, and production and trade statistics on biofuels and their feedstocks, the total acreage required to produce the biofuels consumed in the EU in 2012, is estimated to amount to a maximum 7.8 Mha. The real acreage is probably lower, but a more accurate figure would require detailed insight in current production chains. Of this, 4.3 Mha (58%) is within the EU and 3.1 Mha (42%) resides outside the EU. Increased biofuel production has also led to an increase in water consumption, with 14.0 km$^3$ of water used for EU biofuel production in 2012. This represents a 21% increase when compared to 2010 levels.

III.C. Biofuel sustainability

There are a range of sustainability criteria being used internationally, relevant to the production and use of biofuels. From a regulatory perspective, the key examples are the Renewable Energy Directive in the EU and the Renewable Fuels Standard (RFS) in the US.

III.C.1. Renewable Energy Directive (RED)

Only biofuels that comply with selected criteria can receive government support or count towards national renewable energy targets, under the RED (Article 17 in EC, 2009). Sample criteria include -

- The greenhouse gas emission saving from the use of biofuels shall be at least 60 % for biofuels produced in installations starting operation after 5 October 2015. In the case of installations that were in operation on or before 5 October 2015, biofuels shall achieve a greenhouse gas emission saving of at least 35 % until 31 December 2017 and at least 50 % from 1 January 2018

- Biofuels and bioliquids shall not be made from raw material obtained from land with high biodiversity value, namely land that had one of the statuses as described in Article 17 (3) in or after January 2008

- Biofuels and bioliquids taken shall not be made from raw material obtained from land with high carbon stock, namely land that had one of the statuses as described in Article 17 (4) in January 2008

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26 Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions (2015). https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-293-EN-F1-1.PDF.
Feedstock producers can demonstrate compliance with the above sustainability criteria through one of three ways – i) the use of bilateral agreements, ii) Member State national systems, or iii) voluntary schemes recognized by the Commission. Of the three options, voluntary schemes are increasingly important as they provide producers with certainty that they will comply with all Member States’ requirements regardless of where a feedstock is produced. In terms of national systems, at least 23 of 28 Member States had implementation of Renewable Energy Directive sustainability criteria. Regarding bilateral agreements, none are in place that are recognised by the Commission.

Under the voluntary schemes approach, compliance can be gained through one of 19 voluntary schemes. IATA (2014) state that there are considerable differences between the schemes in terms of the sustainability criteria considered, and that lifecycle analyses aren’t always comparable. This makes it a challenging task to define a preferred set of sustainability criteria that could be accepted for biojet fuel at ICAO level, i.e. by 191 states.

### III.C.2. Renewable Fuels Standard (RFS)

The USEPA enforced standards to ensure minimum levels of biofuels in transportation and associated GHG emission reductions, under the RFS. The expanded RFS (known as RFS2), in 2007, established an objective of 36 billion gallons of biofuel use by 2022. Specific biofuel pathways for aviation are eligible for financial credit under the RFS.

The biofuel objective is sub-divided into 4 categories – conventional, advanced (cellulosic), advanced (biomass-based diesel), and advanced biofuel (unspecified). Each has a mandated reduction in GHGs relative to diesel or gasoline. Biojet kerosene can obtain a tradeable Renewable Identification Number, or RIN, which facilitate compliance under RFS2. They are assigned to each gallon of biofuel according to technology/feedstock pathway and associated emissions reductions. To date, no RINs have been claimed for biojet fuel but United airlines plans to claim RINs for the biojet fuel they plan to take in California. However as stated in the NRDC (2013) brief, while the standard has not traditionally been extended to jet fuel, it has driven considerable investment in second generation biofuel and thus remains relevant. In the near future, it is likely that the RFS will support biomass-derived jet fuel.

A full overview of the permitted pathways and feedstocks under RFS2 can be found in the Ecofys (2014) report Appendix B, Table 13.

The above legislative frameworks (RED and RFS) and many voluntary schemes all seek to develop sustainable biofuel supply for their markets. However, they differ in the scope and details of the sustainability criteria that they cover. For airlines, this can be problematic, particularly for flights

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entering non-EU jurisdictions. Airlines want to know that fuel purchased from any location complies with any given sustainability criteria.

Ecofys (2014)29, on behalf of the IATA, have compared the different sustainability criteria across the main regulatory frameworks (RED / RFS2) and five key voluntary schemes - Biomass Biofuel Sustainability Voluntary Scheme (2BSvs), Bonsucro EU, International Sustainability & Carbon Certification System (ISCC), the Roundtable on Sustainable Biomaterials (RSB), and the Roundtable on Sustainable Palm Oil (RSPO) – and made recommendations of how criteria could be harmonised or gain mutual recognition.

Two proposals across stakeholders gaining most support were mutual recognition of the RED and RFS2 and the development of a meta-standard for aviation biofuels. Mutual recognition between the sustainability standards could enable biofuels for aviation to be traded between the EU and US, increasing potential for its deployment. Streamlining of the two regulatory frameworks, RED and RFS2, could also help develop an internationally accepted approach to biofuels sustainability. The similar key requirements for GHG savings and restrictions on land conversion under both mean that some other differences should not be a major barrier to greater streamlining or mutual recognition.

The second proposal, a meta-standard for aviation biofuels would specify minimum key requirements, such as sustainability principles and/or criteria, that biofuel producers would need to meet in order to be recognised by the aviation industry or governments internationally. A bronze standard would ensure a minimum level of sustainability, with higher standards, silver / gold, allowing for differentiation between airlines but on a voluntary basis. The scheme could be managed by an independent organisation or through existing capability e.g. IATA / ICAO.

III.D. EU and global outlook for biofuels

Information from the World Energy Outlook 201531 (WEO) has been used to provide a global picture of potential biofuel use under a number of scenarios. The four scenarios used in the WEO 2015 analysis include –

- New Policies Scenario – policies in place as of mid-2015, INDC pledges and other declared policy intentions; oil prices hit $80 in 2020 and $128 in 2040.
- Current Policies Scenario - policies in place as of mid-2015
- 450 Scenario - pathway to meet the 2 °C climate goal (450ppm)
- Low Oil Price Scenario – market equilibrium is not attained until the 2020s, with prices in the $50-60/barrel range, reaching $85/barrel in 2040.

Oil prices, important for the uptake of biofuels, are shown in Figure 7 for all the scenarios.

Under the “New Policies Scenario”, with blending mandates in around 60 countries, biofuels in transport are expected to triple, exceeding 4 mboe/d by 2040 (1.4 mboe/d in 2013). The large markets of USA (targeting 36 billion gallons by 2022), Brazil and the European Union all double in size, with considerable increases in China and India also expected. Annual investments in biofuel supply averages $15 billion per year out to 2040, concentrated in the large markets previously mentioned. Under this scenario, the total investment to 2040 in new refineries to meet a tripling in consumption is in the region of $390 billion.

Under the “Low oil price scenario”, biofuel use by 2040 drops to 3.3 mboe/d (compared to 4 mboe/d under the New Policies case). While lower prices do push up oil consumption and therefore blended biofuels, the assumption is that policy support could drop off. In particular, advanced biofuels will appear less commercially attractive.

Under the “New Policies scenario”, the use of biofuels increases (as discussed above), reversing recent decline. In recent years, mandates helped increase global consumption from 19 Mtoe in 2005 (1.2% of transport fuels) to 64 Mtoe in 2013 (3.3% of transport fuels). However, increases in vehicle fuel economy and global economic slowdown have slowed growth. Investment in refining capacity has therefore dropped from $27 billion in 2007 to $4.6 billion in recent years. The “New Policies scenario” assumes continued subsidy support for biofuels, with increased levels to 2020, to compete in the relatively low oil price environment [see Fig. 9.22 in WEO]. 20% of the $5.9 trillion of subsidies for renewables in the period 2015-2040 are to biofuels.

The estimated growth by 2040 is estimated to be 70:30 ethanol / biodiesel, with 20% from advanced biofuels. Road transport shares are expected to increase from 3% to 8% by 2040. For aviation, the outlook is that demand takes hold post-2025, accounting for 1% of total global aviation fuels in 2040. Interestingly, all scenarios put global aviation biofuel consumption at 1 Mtoe per year in 2025, except the 450 case, which estimates over 20 Mtoe. The 1 Mtoe level is much lower than the EU target in 2020.
Table 1. Estimated biojet fuel consumption by scenario, mboe/d (Source: WEO 2015)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2025</th>
<th>2040</th>
<th>2025</th>
<th>2040</th>
<th>2025</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>1.4</td>
<td>2.6</td>
<td>4.2</td>
<td>2.3</td>
<td>3.6</td>
<td>4</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>Road transport</strong></td>
<td>1.4</td>
<td>2.6</td>
<td>4.1</td>
<td>2.3</td>
<td>3.5</td>
<td>3.6</td>
<td>7.6</td>
</tr>
<tr>
<td><strong>Aviation</strong></td>
<td>0.02</td>
<td>0.1</td>
<td>0.02</td>
<td>0.1</td>
<td>0.4</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td><strong>Aviation (Mtoe/yr)</strong></td>
<td>1.0</td>
<td>5.1</td>
<td>1.0</td>
<td>5.1</td>
<td>20.4</td>
<td>92.0</td>
<td></td>
</tr>
<tr>
<td><strong>Share of transport fuels</strong></td>
<td>3%</td>
<td>4%</td>
<td>6%</td>
<td>4%</td>
<td>5%</td>
<td>7%</td>
<td>18%</td>
</tr>
</tbody>
</table>

In terms of regions, the share for the three largest markets (Brazil, USA, and Europe) drops from 86% in 2013 to 66% by 2040, mainly due to growth in China and India. Specifically for Europe, the outlook for biofuels is for consumption to increase from 0.3 to 0.7 mboe/d in 2040 (est. 36 Mtoe) in the New Policies Scenario. The share of biofuels in road transport energy consumption increases significantly, from 5% to 16%.

**III.E. Global Resource potential**

Globally, bioenergy accounts for 10% of total primary energy supply, two-thirds of which comes from traditional biomass (small-scale, local harvested biomass used in cooking and heating). There is a wide range of estimates in the existing literature of the potential for global bioenergy making it difficult to infer how this could impact on biojet fuel for aviation\(^\text{32}\). However the global availability of biomass cannot be measured directly, it can only be modelled. Models vary in complexity and sophistication, but all aim to integrate information — from sources such as the Food and Agriculture Organization’s (FAO) databases, field trials, satellite imaging data and demand predictions for energy, food, timber and other land-based products — to elucidate bioenergy’s future role. The future supply of biomass generally depends on the availability (and productivity) of land for energy crops and food, and the ready supply of residues and wastes from existing and anticipated economic activity\(^\text{33}\).

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As shown in Figure 8, the most important potential sources of biomass are energy crops (22–1,272 EJ), agricultural residues (10–66 EJ), forestry residues (3–35 EJ), wastes (12–120 EJ) and forestry (60–230 EJ). However the wide range in resource estimations must be considered.

### III.E.1. EU resource potential

To meet the 2 Mt target approximately 10-14 Mt of feedstock would be required depending on whether it was waste, agricultural residues or forestry residues. This is assuming feedstock production rates of between 4.5 and 6 tonnes of feedstock per tonne of fuel.

Two recent reports detail and quantify available bioenergy potential in Europe. The first report is from the EU’s JRC while the second is from the ICCT.

The JRC report details available feedstock’s from agriculture, waste and forestry under a 2020 reference scenario, and estimates that approximately 267 Mtoe of bioenergy potential is available. A small percentage of this is from waste (8%) with the remainder split evenly between forestry and agriculture. However, the report emphasises the strong impact sustainability criteria has on future potential, particularly for wood potential which can reduce by around 40% or increase by 100% by 2050, depending on the criteria. Estimated costs for each feedstock under a number of scenarios out to the year 2050 is also presented in detail in the report.

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The High, Reference and Low bioenergy availability scenarios differ in assumptions related to land use, agricultural practices, and protected areas. The High bioenergy scenario is compatible with a situation where mobilisation measures are in place and/or demand for biomass is high, and there is a willingness to pay a (higher) price for it. The Reference bioenergy scenario specifies the most likely future development of bioenergy leading to a continuation of current trends. This implies that bioenergy types with high sustainability risks are avoided and that enough room is left for competing uses of biomass outside the energy sector. In the Low bioenergy scenario, biomass use in the energy sector is not a key priority, but resource efficient use of biomass is. The report also provides a detailed description of costs at the Member State level which could provide a useful starting point in the targeting of regional biofuel policy. An example of these costs is shown in Figure 9.

![Map showing bioenergy potentials](image)

**Table 2: 2020 Bioenergy potentials for the EU28 under three scenario (Mtoe) [Source: JRC]**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low Bioenergy Scenario</th>
<th>Reference Bioenergy Scenario</th>
<th>High Bioenergy Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>96 Mtoe</td>
<td>131 Mtoe</td>
<td>192 Mtoe</td>
</tr>
<tr>
<td>Forestry</td>
<td>91 Mtoe</td>
<td>119 Mtoe</td>
<td>217 Mtoe</td>
</tr>
<tr>
<td>Wastes</td>
<td>13 Mtoe</td>
<td>17 Mtoe</td>
<td>25 Mtoe</td>
</tr>
</tbody>
</table>

Figure 9: JRC Bioenergy Report (2015), sample information on costs. Shown is the Member State levelled cost (€/GJ) for forest residues
The JRC report raises an interesting point on the dynamics between renewable targets and pathways for bioenergy feedstocks, noting that large amounts of bioenergy are likely to be used in all countries devoted to meet the 2020 biofuel production targets. On this basis, by 2030 biofuel production shifts to lignocellulosic-based second generation technologies, resulting in a low use of the available starch, oil and sugar crops potential. In the absence of a specific transport biofuel target, all the biofuel production after 2020 is concentrated in second generation technologies producing mainly wood-based biodiesel to be used in air transport.

The report ‘Wasted’ by ICCT highlights that if all the wastes and residues that are sustainably available in the European Union were converted only to biofuels, this could supply 16% of road transport fuel in 2030. Apart from fuels made from biogenic wastes and residues, the report also highlights the high potential to produce fuels from other feedstocks, such as used cooking oil or industrial waste gases. Currently, around 1.1 million tonnes of used cooking oil is being converted each year to low-carbon fuel in the EU, with potential to expand.
IV. CURRENT AND FUTURE USE OF BIOJET FUEL

Here we discuss recent developments in pathway in biojet fuel development. First, a number of barriers and challenges to the development should be acknowledged. These are detailed in an EC paper in 2013 and are summarized below.

- **Lack of reliable overall biofuel policy**
  
  A number of problems emerge from the current policy.
  
  - Uncertainty, and lack of public and political support
  - Particularly linked to sustainability issues associated with 1st gen. biofuels
  - While aviation has avoided these issues to date, most biojet fuel is produced alongside other biofuels, linking it to policies associated with road transport

- **Lack of policy incentives for aviation biofuels**
  
  - The EU ETS is currently the only policy incentives, which has been subject to numerous difficulties
  - Market incentives for biojet fuel are limited and today’s current biofuel production is geared towards road transport, which is more profitable.

- **Lack of long term off-take agreements between the biofuel producers and the aviation industry**
  
  - There is no technical advantage for airlines to use biofuels; their use actually requires extra effort for blending and quality monitoring arrangements, resulting in additional cost.
  - Current biofuel purchasing is for environmental, not economic, reasons – as part of airline sustainability agendas.

- **Lack of financing**
  
  - Aviation biofuel production is typically higher cost than road transport biofuels. The business case for investing in higher cost projects, with limited markets, and therefore increased risks, make raising capital difficult.

IV.A. Current production pathways for biojet fuel

In 2009, members of the International Civil Aviation Organization (ICAO) approved the use of sustainable alternative fuels as an important option for reducing aviation emissions. At the same time, ASTM International approved the Fischer-Tropsch process as the first production pathway for alternative jet fuel. Two more pathways have subsequently been approved, the third, known as “Synthetic Iso-paraffin” from Fermented Hydroprocessed Sugar (SIP), in 2014.

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All biojet fuels described below are known as ‘drop-in’ fuels, ‘a substitute for conventional jet fuel, which is fully compatible, mixable and interchangeable with conventional jet fuel. Such an alternative fuel does not require any adaptation of the aircraft and or infrastructure, and does not imply any restriction on the domain of use of the aircraft.’

The three approved pathways are described below, and are largely based on information in Lufthansa / Wiweb (2014). The approval of additional pathways is ongoing but none are described here in detail due to the timescales considered in this report. These include Alcohol-to-Jet, pyrolysis and catalytic cracking (Hydroprocessed Depolymerized Cellulosic Jet), catalytic hydrothermolysis and catalytic conversion of sugars.

**IV.A.1. Fischer-Tropsch (FT) process**

- **Process description:** This pathway essentially takes biomass and converts it to liquid fuels that can be used as an alternative to liquid fuels. Prior to the FT process, the biomass feedstock is converted to a syngas (a mixture of CO and H2) via a gasification process. Once cleaned up, the syngas is used in the Fischer-Tropsch process, where a catalyzed chemical reaction converts the syngas into liquid hydrocarbons of various forms. The chemical reaction sees the syngas converted into long chain alkanes / paraffinic waxes or olefins, which are then hydrocracked and isomerized. Finally, the raw product is distilled and separated into individual products, of which kerosene is one.

- **Feedstocks:** This FT process can use a range of feedstocks – coal, gas, biomass. Almost any type of biomass feedstock can be used, as it first goes through the gasification stage, with limited pre-treatment apart from moisture control.

- **Production status:** Sasol (South Africa) and Shell (Qatar) use coal-to-liquids and natural gas conversion respectively, and produce FT blendstock for jet kerosene. While demonstrated at pilot scale, no FT facilities currently produce blendstocks using biomass.

- **Blend limit:** The ASTM approval in 2009 limits the blend ratio to 50% (under specification ASTM D7566). This limit is independent of the feedstock. One of the reasons for the limit is the need for aromatics in the kerosene blend; there are none in the FT blendstocks. The specification therefore states that the blend must have a minimum aromatics content of 8%.

**IV.A.2. HEFA-Kerosene**

- **Process description:** Approved in 2011 by ASTM, the Hydrotreated Esters and Fatty Acids (HEFA) pathway is akin to the refining of crude oils. Initially, waste fats and oils are pre-treated and prepared for the actual production. The prepared material is then reacted with hydrogen (hydrotreatment). This production step removes the oxygen and converts the material into hydrocarbons. These subsequently go through a cracking and isomerization process to produce a mixture of n-alkanes and iso-alkanes. Finally, the raw product is

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distilled and separated into individual products. The production process is the same for all feedstock, although pre-treatment if of course different.

- **Feedstocks:** Feedstocks are more limited than for the FT process. They are fats and oils (triglyceride), including edible oils like palm or rapeseed oil, which are commercially available in large quantities, and oily or fatty wastes, like palm oil press residues or slaughterhouse waste. Diverting edible materials for fuel production purposes is contentious and therefore there has been a tendency for producers to increasingly source waste materials. In 2013, waste and residues already accounted for some 52% of the feedstock used by HEFA market leader, Neste Oil.

- **Production status:** There are several HEFA refineries producing road fuels. The largest is Neste Oil, with a total annual production capacity of two million tons. The largest HEFA kerosene batch for aviation to date has been the 800 tons produced by Neste in 2011 for the Lufthansa burnFAIR in service evaluation. Other smaller facilities producing limited quantities for aviation, include the Dynamic Fuels refinery at Geismar, Louisiana, used by SkyNRG to procure fuel for KLM. No facilities routinely produce HEFA bio kerosene at large scale.

- **Blend limit:** This is the same as for the FT pathway, with a blend limit of 50% (again in part limited due to the absence of aromatics in the blendstock). Specification is covered by Annex 9.2 of ASTM D7566.

**IV.A.3. SIP Kerosene**

- **Process description:** This pathway is Synthesized Iso-Paraffins (SIP) produced from Hydroprocessed Fermented Sugars. There are two major production steps. First, yeast is used to convert plant sugars to farnesene through fermentation, which is 15 carbon, long-chain, branched, unsaturated hydrocarbon. In the second step, farnesene is converted to a modified alkane, a molecule with no double bonds, by reacting hydrogen with farnesene through a catalytic bed. The resulting product is a saturated alkane, farnesane, which is then purified by distillation to produce aviation kerosene.

- **Feedstocks:** SIP fuel is produced using sugar from sugarcane feedstock. However, all kinds of plant sugars could be considered, including cellulosic sugars. SIP could potentially (in the future) be produced from woody biomass, avoiding conflict with food production.

- **Production status:** There is currently only one producer of SIP fuel, Total / Amyris. The farnesene molecule is currently produced at commercial scale in the Amyris plant of Brotas in Brazil, with capacity to deliver 40 kt of fuel per year.

- **Blend limit:** Approval for SIP as a kerosene blendstock was given in June 2014, and is covered by Annex 3 of ASTM D7566. A maximum blend ratio of 10% is permitted; this is due to the blendstock consisting of only one compound, farnesane. (It consists of one carbon chain-length only (C-15) when kerosene’s paraffins include chain-lengths from 9 to 16 carbon atoms).

The approval of additional pathways is still ongoing. These include Alcohol-to-Jet, pyrolysis and catalytic cracking (Hydroprocessed Depolymerized Cellulosic Jet), catalytic hydrothermolysis and catalytic conversion of sugars. A proposal by Boeing using green diesel (also known as renewable diesel) at a low blending ratio (around 10%) is also being considered.
IV.B. GHG emissions from different feedstocks

Whereas all renewable energy sources necessitate some use of natural resources, bioenergy differs in the extent and complexity of its impacts and not all biofuels are created equally. The production of biojet fuel causes upstream emissions, including emissions from growing the feedstock, and from the production, transport, refining and other processes in the parts of the supply chain before it is used in an aircraft. These emissions are excluded from the carbon performance of the biofuel under the EU ETS. Lifecycle GHG emissions can be reported as either ‘default’ or ‘actual’ values. Default emissions saving values are provided for a range of common biofuel supply chains; however biojet fuel is not one of the example chains. Default values are set at a conservative level to provide an incentive to report actual values. Actual values can always be calculated (even if a default value is given) using the methodology provided in Annex V of the RED.

The RED and the FQD have harmonised requirements regarding biofuel sustainability. Similarly, for biofuels to be zero emissions rated in the EU ETS they will also have to demonstrate that they meet the RED sustainability criteria. However, different biojet fuel routes deliver different GHG emission reductions (Figure 10). For example, the 2 Mt EU target for biojet fuel will deliver between 40% to 80% saving on GHG per unit of fuel depending on what feedstock is used (see Figure 11).

Within the RED, GHG emission savings from biofuels are based on the latest available actual average emissions from the fossil part of petrol and diesel consumed in the Community as reported under Directive 98/70/EC. If no such data are available (as in the case of biojet fuel), the value used is 83.8 g CO$_2$eq/MJ.

The FQD includes a detailed methodology for assessing the carbon intensity for biofuels, but for gasoline and diesel only a single default carbon intensity value of 83.8 g CO$_2$e/MJ is provided.
Figure 10: Default GHG emissions based on ANNEX V RED (g CO₂eq/MJ)

Figure 11: Potential GHG savings (Mt) achieved with the 2 Mt target
To place these emissions reduction in context, current EU emissions from aviation are reported at 150 Mt of CO₂; therefore, a 2 Mt biojet fuel target for 2020 could reduce emissions by 2-3%.

Within Europe there are also a number of targeted areas of research with a focus on feedstocks for specific biojet fuel pathway development. For example the ITAKA project targets camelina oil as the best possible sustainable feedstock that can be produced within timescales, at enough quantity within Europe. The ITAKA project is expected to support the development of aviation biofuels and improve the readiness of existing technology and infrastructures. This will be achieved through the development of a full value-chain in Europe to produce sustainable drop-in hydroprocessed Esters and Fatty Acids at large scale. ICAO’s Alternative Fuels Task Force (AFTF) is currently undertaking a projection of sustainable feedstock available for production and use. The availability of different biomass feedstock varies greatly among the different regions of the world. From a sustainability and emissions perspective, wastes and residues seem the most attractive feedstock.

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V. CURRENT AND FUTURE BIOJET FUEL PRODUCTION CAPACITY

Current production estimates for biojet fuel for aviation use is more difficult to determine due to the relatively recent emergence of these types of fuels. Much of the production is being done by established biofuel producers in partnership with airlines. IATA reports that 21 agreements between airlines and producers are recorded in the Global Framework on Aviation Alternative Fuels (GFAAF), the ICAO database tracking alternative jet fuels40.

Table 3 provides an overview of some of the key partnerships – and what that means in terms of current or future production volume (Table 4). There are also many other biofuel test activities and new flights beyond those listed below that use primarily HEFA pathways, supplied by leading producers such as SkyNRG and Neste Oil. The farnesene-based SIP fuel is also increasing in use across a range of airlines. A comprehensive database of biojet fuel-based flights is the BioJetMap41.

<table>
<thead>
<tr>
<th>Airline</th>
<th>Producer</th>
<th>Feedstock-Pathway</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOL (Brazil)</td>
<td>UOP / Amyris-Total</td>
<td>HEFA-Inedible corn oil &amp; used cooking oil /</td>
<td>Target of blending 1% of biofuels in their jet fuel by 2016. Achieved 200 flights with a 4% biofuel mixture during the FIFA World Cup, using 92,000 L of HEFA supplied by UOP. Using SIP,</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Airline</th>
<th>Producer</th>
<th>Feedstock-Pathway</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLM</td>
<td>SkyNRG</td>
<td>HEFA-Used cooking oil</td>
<td>New series of 20 weekly intercontinental flights from Amsterdam to Aruba, using a 20% blend of biofuels made from used cooking oil. (KLM Corporate Biofuel Programme enables businesses to ensure that some of their corporate travel is undertaken using sustainable biofuel. Participants pay a surcharge that covers the difference in cost between biofuel and traditional kerosene) <a href="https://klmtakescare.com/en/content/biofuel-because-">https://klmtakescare.com/en/content/biofuel-because-</a></td>
</tr>
<tr>
<td>Lufthansa</td>
<td>Neste Oil</td>
<td>HEFA-Used cooking oil</td>
<td>Project burnFAIR is part of a larger umbrella program FAIR, that also researches issues outside biomass. <a href="http://aireg.de/images/downloads/Abschlussbericht_BurnFAIR.pdf">http://aireg.de/images/downloads/Abschlussbericht_BurnFAIR.pdf</a></td>
</tr>
</tbody>
</table>

Table 3. Airline-fuel producer partnerships (Source: IATA, 2015\(^42\))

Interestingly, many of the larger supply agreements (Cathay and United) are yet to start supplying, two of which are based on FT bioenergy processes, which to date have not been used at scale. To

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date, most of the supply is based on the HEFA pathway, with some limited use of SIP fuels (at a 10% blend).

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Technology</th>
<th>Production cap (t/yr)</th>
<th>Planned aviation biofuel cap (t/yr)</th>
<th>Start-up date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neste Oil</td>
<td>Netherlands</td>
<td>HEFA</td>
<td>800,000</td>
<td>*</td>
<td>2011</td>
</tr>
<tr>
<td>Neste Oil</td>
<td>Singapore</td>
<td>HEFA</td>
<td>800,000</td>
<td>*</td>
<td>2010</td>
</tr>
<tr>
<td>Neste Oil</td>
<td>Finland 1</td>
<td>HEFA</td>
<td>190,000</td>
<td>0</td>
<td>2007</td>
</tr>
<tr>
<td>Neste Oil</td>
<td>Finland 2</td>
<td>HEFA</td>
<td>190,000</td>
<td>15,000</td>
<td>2009</td>
</tr>
<tr>
<td>UOP</td>
<td>Italy</td>
<td>HEFA</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UOP</td>
<td>Spain</td>
<td>HEFA</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BTG</td>
<td>Netherlands</td>
<td>HPO</td>
<td>1,000,000</td>
<td>50-100,000</td>
<td></td>
</tr>
<tr>
<td>Evergent Techn.</td>
<td></td>
<td>HPO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neste/Stora Enso</td>
<td>Finland</td>
<td>FT</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ForestBTL Ajos</td>
<td>Finland</td>
<td>FT</td>
<td>140,000</td>
<td>0</td>
<td>2017</td>
</tr>
<tr>
<td>UPM/Carbona</td>
<td>France</td>
<td>FT</td>
<td>100,000</td>
<td>0</td>
<td>2017</td>
</tr>
<tr>
<td>CEA</td>
<td>France</td>
<td>FT</td>
<td>22,000</td>
<td>15,000</td>
<td>2018</td>
</tr>
</tbody>
</table>

* Potentially could produce tens of thousands of tons capacity to renewable aviation fuel production if demand exists.

Table 4. European current or planned production capacity for biofuels, and potential biojet fuel production
(Source: EC, 201343)

In the near term, it is likely that HEFA will provide the main means for scaling up production in Europe and globally. FT is likely to play a stronger role towards the end of the decade and into the 2020, with other new emerging pathways (such as alcohol-to-jet). Therefore, the above FT projects listed in addition to those in the USA (Fulcrum, Red Rocks) have a key role to play in demonstrating the technology at scale.

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VI. MARKET-BASED MEASURES FOR BIOJET FUEL DEVELOPMENT

Market-based measures (MBM) have long been held as an economically efficient approach to tackling the problem of rising GHG emissions. With technological potential for emissions reduction limited in the aviation sector, MBMs can help to offset strong emission growth through funding emission reductions in other sectors. The EU led the way in implementing MBMs by including aviation in its Emission Trading System (EU ETS). However, it is also worth remembering that ultimately the long-term goal of the Paris Agreement necessitates a net-zero targets, which requires absolute reductions in all sectors.

A question remains whether such measures can effectively increase the uptake of biojet fuels in the EU, particularly given the existing cost differential between kerosene and biojet fuel.

VI.A. ICAO led initiatives

As far back as 2001, the ICAO Assembly initiated work to develop guidance for Member States (of ICAO) on the application of MBMs aimed at reducing or limiting the environmental impact of aircraft engine emissions. One of the principal findings of the ICAO work was that an emissions trading system could serve as a cost-effective measure to limit or reduce CO₂ from the civil aviation sector in the long term, provided that it is open to all economic sectors. Currently, ICAO and its members are looking to propose a global MBM, as agreed under Assembly Resolution A38-18, (adopted by the 38th ICAO Assembly in October 2013), to achieve a collective medium term global aspirational goal of keeping the global net CO₂ emissions from international aviation from 2020 at the same level (carbon neutral growth from 2020, or CNG2020). The timetable for the global MBM is that the ICAO Council will report back to the 39th ICAO Assembly in October 2016, with a recommendation for a scheme. If agreed by Member States, the scheme will be implemented from 2020 onwards. It is not clear how the global MBM will be designed, and what impact it may have on the use of biofuels across the industry.

As of 2012, three options for a MBM were under consideration - global mandatory offsetting, global mandatory offsetting with revenue, and global emissions trading. The first option is a scheme where emissions units are acquired to offset CO₂ above an agreed target. For example, to keep emissions at 2020 levels, 464 Mt CO₂ would need to be offset in 2036. Emissions units would need to comply with agreed eligibility criteria to ensure adequacy of emissions reductions. The second option also produces a revenue stream, perhaps through transaction fees for each unit offset, which can be recycled into other mitigation activities. The final trading scheme option would cap total emissions and allow for aviation allowances to be traded. The first option is the least complex since existing emissions units would be used and tracked through a simple registry.

The ICAO (2013) assessment suggests that the introduction of an MBM would have limited impact on the cost base in 2036, lowering traffic growth by 3% (107% compared to 110% growth), reducing profits by $0.4 billion to $33.3 billion, and increasing costs to consumer to approximately

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$10 per seat for a flight of 10,000 to 12,000 kilometres and $1.50 per seat on a flight of 900 to 1,900 kilometres. Following a round of dialogues on prospective design of the MBM, it is still not clear what design of scheme will emerge.

Emerging from the MBM discussion, it is likely that there will be a crucial role of offsetting, to help meet the target of stabilizing international aviation’s carbon dioxide emissions by the year 2020. As discussed, there is a potentially large gap between carbon neutral growth and actual emissions, necessitating some sort of trading / offsetting (Lee et al. 2013). There are four potential sources of supply for offsetting:

- Emission allowances from national or regional cap and trade programs.
- Emission allowances created under the Kyoto Protocol at the national level.
- Credits from UN registered emission reduction projects.
- Credits from voluntary offset projects.

Currently, allowances in the EU ETS (see next section) trade at around $6/t, certified emission reductions (CERs) and emission reduction unit (ERUs) are less than $1/t, and voluntary offsets are about $6/t. The BNEF/EDF analysis concludes that there is plenty of supply and at relatively low cost (although unit costs are expected to grow out to 2050; analysis assumed they reached $25-33 in 2050).

In conclusion, the low cost impact of an offset-based MBM reflects the relatively low price in the offset markets. If airlines can meet 100% of their obligations using offsets it is probable that few will push towards expanding their use of biofuels, which is a much more costly means of reducing emissions. Given the timing of this scheme, it is unlikely to impact on the uptake of biojet in view of the 2020 objective. There is a risk more broadly, set out by Hooper et al. (2010), that an offset-focused MBM could actually lead to other measures not being undertaken. They note that offsetting could slow the transition to low carbon technologies, operating systems and business practices. Ultimately the aviation industry needs to take actual measures to reduce emissions itself; recent analysis by Schäfer et al. (2015) suggests that there is considerable potential to reduce emissions through non-technical measures before even considering alternative fuels.

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46 Lee, D. S., Lim, L. L., & Owen, B. (2013). Bridging the aviation CO2 emissions gap: why emissions trading is needed. Dalton Research Institute, Dept. of Environmental And Geographical Sciences, Manchester Metropolitan University, Manchester, UK.
VI.B. The EU ETS

Emissions of GHG’s from power plants, factories and other fixed installations electricity sector are governed by Directive 2009/29/EC on the EU Emissions Trading Scheme (EU ETS). The scheme coverage is 45% of total EU’s greenhouse gas emissions. The overall volume of greenhouse gases that can be emitted is limited by a ‘cap’ on the number of emission allowances. The cap, which is EU wide and not set at MS level, is limited to 2,047 MtCO$_2$e in 2014. Individual companies operating within these sectors receive and / or must buy emission allowances which they can trade as needed. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005. By 2030, the Commission proposes that they will be 43% lower.

The ETS faces a challenge in the form of a growing surplus of allowances, largely because of an initial oversupply and the recent economic crisis which has depressed emission levels more than anticipated. Efforts to address the market imbalance would also be helped by a faster reduction in the EU ETS cap. To achieve the target of a 40% reduction in EU greenhouse gas emissions below 1990 levels by 2030, set out in the 2030 framework for climate and energy policy, the cap will need to be lowered by 2.2% per year from 2021, compared with 1.74% currently. Revisions to the ETS are discussed in another Insight-E report.

The aviation industry joined the EU Emission Trading Scheme in 2012. Initially the EU ETS was set to cover 100% of EU aviation emissions, which equated to a third of global aviation emissions. However, in April 2013, the EU decided to temporarily suspend enforcement (a move called ‘Stop the Clock’) of the EU ETS requirements for flights operated in or to non-EU countries, while continuing to apply the legislation to flights within and between countries in Europe. It is intended that this allows time for agreement on the global MBM, as discussed in the previous section. The initial full-scope EU ETS proposed to cover about 35% of global emissions (i.e. emissions from domestic and international flights) and about 50% of emissions from international aviation. As the "stop-the-clock" option only covers intra-EEA flights and flights to and from closely connected areas but not flights to other non-EEA countries, it only achieves 26% of the originally intended full-scope EU ETS emissions coverage.

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Exemptions for operators with low emissions have also been introduced. Free aviation allowances are allocated to more than 900 aircraft operators who applied for free allocation by reporting their verified tonne-km data for 2010. The cap on emission for aviation is not the same as the general ETS. The cap is set to an equivalent of 95% of 'historical' emissions as specified in the EU regulation on aviation in the EU ETS.\textsuperscript{52}

The emissions cap for aviation is different to the declining annual cap provided for the other economic sectors included in the EU ETS. The 2012 aviation cap was set at 97% of the average aviation emissions over 2004-2006, dropping to 95% for the period of 2013-2020. In 2012 the majority (82%) of allowances making up the cap were given away for free, with the remaining 15% being auctioned and the remaining 3% allocated to a special reserve for fast growing and new entrant airlines. Unlike the EU ETS in general where the number of free allowances issued to static installations decrease over time, in the aviation sector the handout remains steady up to 2020.

Each aircraft operator is administered by a single Member State. Aircraft operators based in the EEA are administered by the Member State that issued their operating licence. In all other cases, the operator is administered by the Member State with the largest estimated attributed aviation emissions from that operator in the base year. Aircraft operators were required to report 2013

aviation emissions – based on the reduced scope of the EU ETS – by 31 March 2015 and to surrender a corresponding amount of allowances by 30 April 2015.

From empirical evidence on ticket prices for consumers based on a sample of EU and US airlines, the EU ETS seems to lead to price increases between 0.43 % and 0.94 % for passenger tickets (excluding taxes and charges). Ryanair has published figures of the cost to passengers of climate change measures. These are cited as being €0.25 for passengers flying from continental Europe, and £0.25 for passengers buying tickets in the UK.

From an airline’s perspective, currently the only legislative driver for reporting biojet fuel use is the EU ETS. The ETS currently requires airport (aerodrome) level reporting. Beyond the potential impact of the RED, where Member States can include aviation biojet fuel in their obligation schemes, the EU ETS could be an additional mechanism for promoting biojet fuel uptake in the sector. Biojet fuel is counted as zero-emissions under the EU ETS (as it is for bioenergy), where the sustainability requirements (in Article 17) of the RED are complied with. Furthermore, the biojet fuel reported may not exceed the total fuel usage of an airline for their flights departing from a specific airport that is within the EU ETS, to avoid that airlines can get substantial exemptions from the EU ETS by using biojet fuel mainly on routes not subject to the EU ETS.

However, the carbon price under the EU ETS is insufficient to incentivise the use of biojet fuel for reducing emissions. An ETS price far in excess of today levels (of over €200/tCO₂) would be required to establish price parity between jet kerosene and biojet fuel. It is unlikely that prices will have increased sufficiently by 2020 to significantly contribute to 2020 biojet fuel objective.
VII. BIOJET FUEL COST DIFFERENTIAL

The Biofuel FlightPath Initiative was introduced in June 2011. The European Commission in collaboration with the aviation industry and biofuel producers are targeting 2 Mt annual production of fuel derived from renewable sources by 2020. This equates to approximately 1% of the total projected global jet fuel consumption in 2020 or 4% of EU jet fuel consumption. To put this in context, in 2013 approximately 13.1 Mt of biofuels were consumed in all forms of transport in Europe.

Current kerosene prices are almost at their lowest in 10 years, making the economics of biojet fuel very challenging. In addition, a high percentage of airlines hedge a proportion of their future fuel needs 6 to 24 months in advance by buying jet fuel to reduce price-fluctuation risk on projected operating costs. For example, Ryanair fuel is 95% hedged at approximately $62/bbl (0.34€/l) and €/$ is hedged at $1.17. For the year 2018 Ryanair have just over 50% hedged at approximately $52/bbl.

The cost differential between 2 Mt of conventional jet kerosene compared to biojet fuel provides an idea of the sum of money that needs to be recovered to cover the difference in production costs. In this report we call this the Biojet Fuel Cost Differential. Once the amount is established then a

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53 This includes Airbus, Air-France-KLM, British Airways, Lufthansa and biofuel producers Chemtex Italia, Neste Oil, Biomass Technology Group, UOP and Swedish Biofuels.
54 RyanAir website. corporate.ryanair.com/news/news/160201-q3-profit-of-103m-up-54m/?market=en
cost recovery mechanism is required to raise it. Table 2 details the sums of money to be recovered depending on the cost differential between biojet fuel and kerosene. These sums only cover costs in relation to production costs and do not allow for administrative or any other costs. If for example the cost differential between jet kerosene and biojet fuel was 0.50 €/L, this would give a cost of 1.3€b for the Biojet Fuel Cost Differential.

<table>
<thead>
<tr>
<th>Biojet fuel cost differential</th>
<th>2.0 Mt</th>
<th>1.7 Mt</th>
<th>1.5 Mt</th>
<th>1.2 Mt</th>
<th>0.9 Mt</th>
<th>0.6 Mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.20 €/L</td>
<td>3,041 €m</td>
<td>2,607 €m</td>
<td>2,172 €m</td>
<td>1,738 €m</td>
<td>1,303 €m</td>
<td>869 €m</td>
</tr>
<tr>
<td>1.10 €/L</td>
<td>2,788 €m</td>
<td>2,390 €m</td>
<td>1,991 €m</td>
<td>1,593 €m</td>
<td>1,195 €m</td>
<td>797 €m</td>
</tr>
<tr>
<td>1.00 €/L</td>
<td>2,534 €m</td>
<td>2,172 €m</td>
<td>1,810 €m</td>
<td>1,448 €m</td>
<td>1,086 €m</td>
<td>724 €m</td>
</tr>
<tr>
<td>0.90 €/L</td>
<td>2,281 €m</td>
<td>1,955 €m</td>
<td>1,629 €m</td>
<td>1,303 €m</td>
<td>978 €m</td>
<td>652 €m</td>
</tr>
<tr>
<td>0.80 €/L</td>
<td>2,027 €m</td>
<td>1,738 €m</td>
<td>1,448 €m</td>
<td>1,159 €m</td>
<td>869 €m</td>
<td>579 €m</td>
</tr>
<tr>
<td>0.70 €/L</td>
<td>1,774 €m</td>
<td>1,521 €m</td>
<td>1,267 €m</td>
<td>1,014€m</td>
<td>760 €m</td>
<td>507 €m</td>
</tr>
<tr>
<td>0.60 €/L</td>
<td>1,521 €m</td>
<td>1,303 €m</td>
<td>1,086 €m</td>
<td>869 €m</td>
<td>652 €m</td>
<td>434 €m</td>
</tr>
<tr>
<td>0.50 €/L</td>
<td>1,267 €m</td>
<td>1,086 €m</td>
<td>905 €m</td>
<td>724 €m</td>
<td>543 €m</td>
<td>362 €m</td>
</tr>
</tbody>
</table>

Table 5. Biojet Fuel Cost Differential (€m) for varying levels biojet fuel penetration (Mt) and varying price differential between kerosene (€/L)

**Box 2: Biojet Fuel Cost Differential: Context**

Table 5 helps contextualize the sums of money involved in the equalization of cost recovery for biojet fuel. The amounts are not trivial and are amplified with an increasing target and lower kerosene costs. To put the biojet fuel differential in the context: In 2014, €7.5 billion was billed in respect of route charges for flights operated from in the airspace of the 39 Contracting States. For low cost airlines such as Ryanair, existing route charges can make up approximately 12% of their total operating expenses. This is more than staff costs and compares to 40% for fuel costs.

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VIII. MODULATION OF AIR NAVIGATION CHARGES TO ASSIST BIOJET FUEL

A potential mechanism to recover the Biojet Fuel Cost Differential is to spread the cost across aviation route charges in Europe. Currently the EUROCONTROL Route Charges System funds the costs of en-route air traffic management (ATM) services provided by EUROCONTROL’s Member States, based upon the “user pays” principle.

VIII.A. Overview of current charging scheme

In Europe, the costs of air traffic management services (infrastructure, staff and other operational costs) are funded through air navigation charges. There are different types of air navigation charges: route charges, terminal navigation charges, and communication charges. Charges are directly cost-related and are calculated in a transparent manner. The existing charging scheme introduced under The Single European Sky (SES) is based on Articles 14, 15 and 16 of Regulation (EC) No 550/2004 (the Service Provision Regulation) and detailed in the recently revised Commission Implementing Regulation (EU) No 391/2013 adopted on 3 May 2013.

The charging scheme covers the list of services that can be financed by air navigation charges (for both en-route and terminal services), the means by which the costs of these services must be established and made transparent to airspace users, and the calculation of unit rates and charges for each charging zone using a common formula. According to Article 16 of the Charging Regulation (see Box 3), Member States may decide to modulate air navigation charges to increase the efficiency of air navigation services (ANS) and to promote their optimal use. Notably for the case of biojet fuels, Article 16 (b) also states that Member States may modulate air navigation charges incurred by airspace users to reflect their efforts made in particular to reduce the environmental impact of flying.

Box 3: Article 16 of Regulation (EC) No 550/2004: Modulation of air navigation charges

1) Member States, following the offer to consult provided for in Article 9 may, at national or functional airspace block level and on a non-discriminatory and transparent basis, modulate air navigation charges incurred by airspace users to reflect their efforts made in particular to:

   (a) optimise the use of air navigation services;

   (b) reduce the environmental impact of flying;

   (c) reduce the overall costs of air navigation services and increase their efficiency, in particular by modulating charges according to the level of congestion of the network in a specific area or on a specific route at specific times.

The modulation of charges shall not result in any overall change in revenue for the air navigation service providers.

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service provider. Over- or under recoveries shall be passed on to the following period.

2) Air navigation charges may also be modulated, on a non-discriminatory and transparent basis, to accelerate the deployment of SESAR ATM capabilities. The modulation may in particular aim at giving incentives to equip aircraft with systems included in the common projects referred to in Article 15a(3) of Regulation (EC) No 550/2004.

3) The modulation of air navigation charges means a variation of the en route charge and/or the terminal charge calculated on the basis of the provisions of Articles 11 and 12.

4) National supervisory authorities shall monitor the proper implementation of the modulation of air navigation charges by air navigation service providers.

VIII.B. Review of Current Route Charges

Air navigation service providers (ANSPs) from Member States participating in the Route Charges System recover the cost for facilities and services provided to airspace users by means of route charges. A charge is levied for each flight in the airspace falling within the competence of the Contracting States. This charge takes into account the distance flown and, less than proportionately, the aircraft weight.

The total charge per flight collected by EUROCONTROL (R) equals the sum of the charges ($r_i$) generated in the charging zones defined by States:

$$R = \sum_n r_i$$

Where:

$$r_i = d_i \times p \times t_i$$

The individual charge ($r_i$) is equal to the product of the distance factor ($d_i$), the weight factor ($p$) and the unit rate ($t_i$). **Note that $d_i \times p$ is defined as the number of service units in a charging zone ($i$).** The distance factor ($d_i$) is equal to one hundredth of the great circle distance, expressed in kilometres, between the aerodrome of departure within (or the point of entry into) the charging zone ($i$) and the aerodrome of first destination within (or the point of exit from) that charging zone. The unit rate is a function of Air Traffic Services costs, which include a communication, navigation, surveillance, and aeronautical information, and the costs to EUROCONTROL for their services in collecting fees and regulating the charging zones. Variation in unit rates between Member States is a

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57 This is the shortest distance between two points on the surface of a sphere, measured along the surface of the sphere (as opposed to a straight line through the sphere’s interior).
result of factors such as cost of living differences, and the levels of traffic through Member States’ airspace (Coyne and Baeri, 2014)\textsuperscript{58}.

The entry and exit points are the points at which the lateral limits of the charging zone are crossed by the route described in the last filed flight plan. This flight plan incorporates any changes made by the operator to the flight plan initially filed as well as any changes approved by the operator resulting from air traffic flow management measures. The distance to be taken into account is reduced by a notional twenty kilometres for each take-off and for each landing within a charging zone. The weight factor ($p$) is the square root of the quotient obtained by dividing by fifty (50) the number of metric tonnes in the maximum certificated take-off weight (MTOW) of the aircraft as follows:

$$p = \sqrt{\frac{MTOW}{50}}$$

Box 4: Example of a specific route charge calculation

A sample calculation on route charges for a flight from London Heathrow Airport (EGLL) to Bonn (EDDK) in October 2015 is presented here. The aircraft used is assumed to be of the Boeing 737-800 series type with a Maximum take-off weight of 78 metric tons. This gives a weight factor of 1.25. This calculation was performed with EUROCONTROL’s RSO Distance tool. The total distance flown is approximately 500 km. This gives a distance factor of 5.0. Therefore, the number of service units is 6.25. The flight will pass over the following Member States (or Zones) with the following unit charges [United Kingdom (EG) 189.85€, Belg.-Luxembourg (EB) 234.49€, the Netherlands (EH) 8.34€, Germany 77.85€ (ED)]. The total route charges for this flight amounts to approximately €510.

EUROCONTROL’s Central Route Charges Office (CRCO) bills and collects route charges on behalf of all EUROCONTROL’s Member States. Aircraft operators are charged a single amount per flight, irrespective of the number of States overflown, thus providing a convenient and efficient system for collect and payment of charges.


The individual unit rates vary by charging zone, with zones largely corresponding to regions of airspace managed by individual ANSPs. Another way to view the calculation is in terms of ‘Service Units’. As mentioned previously, the number of service units is equal to the weight factor (i.e. the square root of the MTOW divided by 50) multiplied by the distance factor (i.e. the great circle distance between the entry and exit points at which the route indicated in the last filed flight plan crosses the charging zone boundary). For a given flight and a given charging zone, the route charge is equal to the number of service units multiplied by the unit rate.

Within two to three weeks of the month during which the flights were performed, the following documents are issued to users:

- The bill (issued every month). The date by which payment must be made is shown on the bill and is 30 days from the date of the bill;
- The pro forma statement/statement of flights, which accompanies each bill. It contains a log of all billed flights;
- The statement of account, which shows all the movements of the aircraft operator’s account (e.g. bills sent, payments made, credit/debit notes issued);
- In addition, users may receive credit notes and bills for interest on late payment, as well as Value Added Tax (VAT) invoices on behalf of those States where route charges are subject to VAT.

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59 https://www.eurocontrol.int/
VIII.B.1. Service Units Forecast

EUROCONTROL provide a Seven-Year Forecast of Flight Movements and Service Units 2015 – 2021 in an annual publication\(^{60}\). In 2015, 136.8 million en-route service units (TSU) are expected to be produced in the CRCO14\(^{61}\) area, corresponding to a growth of 3.6% (±1.3 pp) compared to 2014. The number of service units in a charging zone depends on the number of flights, the weight of aircraft and, in the en-route case, the distance flown. The two service unit forecasts therefore take the flight forecast as an input and combine this with time series forecasts of weight and distance as needed. This gives total service units, from which future chargeable service units are estimated using the ratio of chargeable/total from the previous calendar year. Figure 15 provides details the existing unit rates, actual service units in 2014 and forecasted service unit in 2020 across the EU 28 region.

![Figure 15. Actual and forecast service unit levels, and unit rates by Member State. (Source: EUROCONTROL\(^{68}\))](image)


\(^{61}\) CRCO14 stands for the sum over all States participating in the Multilateral Route Charges System in 2014 of all TSU either measured or forecasted for the corresponding year
VIII.C. Use of route charging for funding Biojet Fuel Cost Differential

If the Biojet Fuel Cost Differential is to be recovered through the route charging scheme, then a Central Agency or department (possibly housed with EUROCONTROL) will be required for collection and administration of the system. The position and role of this agency would be strategically important given that this area shares interests and competences between different parts of the Commission; DG CLIMA leads on the EU ETS, DG MOVE on aviation and DG ENER on bioenergy. The location and formation of this agency would need to be discussed with the multiple stakeholders.

The Biojet Fuel Cost Differential amount would have to be determined in a clear and transparent fashion to ensure confidence in any emerging mechanism. This is critical given the market cost of kerosene can vary from location to location. The challenge therefore is to create a system that will encourage innovation and price signals that will reduce the costs of biojet fuel in an efficient manner.

One concept for the modulation of charges is to spread the Biojet Fuel Cost Differential across all service units. Such an approach has two key advantages; firstly, the additional costs are equitably spread based on an aircraft activity basis (weight of the aircraft and the distance travelled across the airspace) in the EU. However, similar to the current route charging scheme it does not account for fuel efficiency of aircraft to be directly included. Secondly, the route-charging scheme is established and provides an existing framework for charging and collecting payments from airspace users.

From a simplistic view, an extra charging component could be added to existing route charges to reflect the additional cost of biojet fuel per service unit and would be equal to:

\[
\frac{[\text{EU wide target biojet fuel target}] \times [\text{Biojet fuel cost differential}]}{[\text{Total no. of service units}]} \]

Based on a biojet fuel target of 2 Mt and a cost differential of €0.50, an estimated €1.3 bln is the resulting Biojet Fuel Cost Differential, and the total additional cost that would need to be recovered through the route charging scheme. By spreading this cost across the projected service units in 2020, (123.8 million), this would result in an additional cost of €10.20 per service unit.

For the flight example in Box 4 this would mean the following. The service units is the product of the distance factor and weight factor which is 5.0* 1.25 = 6.25 service units. At an additional cost of 10.20€ per service unit translates to 63.75€ for the flight. Assuming 160 passengers on the flight results in an extra 0.40€ per passenger.

There are however a number of challenges to effective implementation –

1. How is the Biojet Fuel Cost Differential established, in the absence of a mature fuel supply market?
2. How do the funds raised through route charges feed back to the biojet fuel suppliers?
3. How does the Commission ensure that the equivalent biojet fuel is supplied as a result of the route charge adder?
In Figure 16, we discuss an approach to implementation, which could overcome the above challenges. An annual biojet fuel auction or brokerage would be established, the purpose of which is threefold:

- Establish the price of biojet fuel, either based on a weighted average through tracking of sales, or by establishing a market price based on a real auction. This deals with challenge 1.

- Issue of certificates for purchasing of biojet fuels, to allow for a route charge refund. This deals with challenge 2. If participating in the auction, airlines will gain certificates to the level of the purchase made, which then can be surrendered to gain a route charge refund. This effectively ensures that the funds raised get back to the suppliers.

- Monitoring the biojet fuel purchasing level, to ensure the 2020 objective is met. This effectively deals with challenge 3, allowing for the level of supply to be monitored.

The biojet fuel price determined in the auction / brokerage process allows for the cost differential to be determined, and the cost adder per service unit to be estimated. This is paid by the airlines through the route charge scheme, creating a biojet fuel fund. Built into the scheme is an incentive mechanism for airlines to purchase biojet fuel in the auction, as this could reduce the costs of the biojet fuel differential route charge that all airlines have to pay. If an airline, called ‘X’, simply pays the route charge but does not participate in the auction, this is a higher cost route than an airline, called ‘Y’ that fully participates in the auction. There are two elements of the incentive; first is the ‘differential adjustment’ or an ‘opt out’ option that ensures that payment of the additional route charge without participation in the auction will always be more costly, as explained below. Secondly, if airlines can guarantee supplies at a lower cost than the resulting price determined through the auction, they can also make considerable savings; again this is described in detail below.
The following example, Table 6, shows how the scheme could work for three different airlines, depending on their participation in the scheme –

- Airline X, with a 5 million-service unit level in 2020, participates to a limited extent in the auction, with limited savings gained from full payment of the additional route charge.

- Airline Y, with the same service unit level, participates fully in the auction, purchasing the equivalent biojet to cover the service unit level, but at the resulting auction price.

- Finally, airline Z, with the same service unit level, participates fully in the auction, purchasing the equivalent biojet to cover the service unit level; however, a supplier partnership enables the biojet to be purchased at €1.3/litre, lower than the resulting auction price that feeds into the additional route charge.

The example is premised on the auction delivering the 2 Mt supply of biojet fuel required in 2020. All airlines pay the same route charge adder per service unit, which is based on the cost differential to meet the 2020 target, spread over total service units. This is estimated in row $j$, at 55.5 €m, for all three airlines. The incentive is for airlines to participate in the auction, purchasing biojet fuel to a level that is equivalent to the service unit level. This is worked out simply by dividing the target level by service units (row $k$). For every service unit, the airline can purchase 20.7 litres of biojet fuel, at a lower cost than the additional route charge per service unit. 20.7 litres of biojet fuel at the auction price is €10.33 compared to €11.11 service unit adder (row $i$). This is a 7.5% saving, based on the differential adjustment used (row $g$). Further savings can be made if an airline can guarantee a
biojet fuel cost below the auction price level. If purchasing biojet fuel, an airline will get a certificate (at auction) for every 20.7 litres purchased. This certificate can be surrendered to EUROCONTROL for a refund on the route charge cost adder. This means that those airlines that have paid for the biojet fuel get access to the refund, which effectively routes the funds raised back to the suppliers.

Airline X only purchases biojet fuel that covers an equivalent 10% of service units (row m), limiting savings to 0.4 €m from a total extra charge of €55.5 €m (row o). Airline Y purchases 100% of the equivalent biojet fuel at the emerging auction price, leading to a 7.5% saving of 3.9 €m. Airline Z does the same but has a supplier agreement which mean the cost of biojet fuel is below the emerging auction price. The saving is 24.5 €m. This last example could help incentivise stronger supplier-airline partnerships, and allow airlines to significantly reduce their additional route charge. If airlines are making the purchase of biojet fuel at the auction price, the adjustment differential is crucial. This incentive level will require further consideration, to assess if it provides the necessary incentives to participate in the auction process.

<table>
<thead>
<tr>
<th>Units</th>
<th>All airlines</th>
<th>Airline X</th>
<th>Airline Y</th>
<th>Airline Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Service unit level in year X</td>
<td>Millions</td>
<td>123.8</td>
<td>5</td>
</tr>
<tr>
<td>b</td>
<td>Jet kerosene price (as per market)</td>
<td>€/litre</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>Biojet fuel price (under auction)</td>
<td>€/litre</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>d</td>
<td>Biojet fuel price differential (based on auction) [c-b]</td>
<td>€/litre</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>e</td>
<td>Biojet fuel target in 2020</td>
<td>Mt</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Min litres</td>
<td>2558</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>Cost differential [e*d]</td>
<td>€ bln</td>
<td>1.28</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>Differential adjustment</td>
<td>%</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>Adj. cost differential [f*g]</td>
<td>€ bln</td>
<td>1.37</td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>Service unit adder [h/a]</td>
<td>€/SU</td>
<td>11.11</td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>Total additional route charge [i*a]</td>
<td>€m</td>
<td>1374.9</td>
<td>55.5</td>
</tr>
<tr>
<td>k</td>
<td>Equiv. Biojet fuel purchase per service unit [e/a]</td>
<td>litre/SU</td>
<td>20.7</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>Equiv. Biojet fuel purchase to avoid charge [k*a]</td>
<td>Min litres</td>
<td>103.3</td>
<td>103.3</td>
</tr>
<tr>
<td>m</td>
<td>Actual purchase level, % of equivalent</td>
<td>%</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>n</td>
<td>Cost of biojet fuel purchase [m<em>l</em>d]</td>
<td>€m</td>
<td>5.2</td>
<td>51.7</td>
</tr>
<tr>
<td>o</td>
<td>Savings from biojet fuel purchase [(m*j)-n]</td>
<td>€m</td>
<td>0.3</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Table 6. Sample Calculations for proposed system of recovery
Key issues in determining the design of the scheme are as follows –

- The mechanism for ensuring the level of the target is met through the auction process. There is a question concerning the need for a requirement to mandate the level, ramping to 2 Mt by 2020. Also airline purchases of biojet fuel outside the auction process would need to be accommodated and accounted for.

- The differential adjustment (row g) level needs to be properly determined, to ensure the incentive is sufficient.

- The costs of auction / brokerage need to be considered. This does not necessarily need to be a permanent institution, but rather a one-off event – to monitor the annual supply / purchase level, issues certificates and determine the price.

- Additional costs to EUROCONTROL, to amend software systems to account for the cost adder, and allow for refunds.

- The basis for the service unit level needs to be determined, mostly probably based on historical levels (previous year) but potentially on projected estimates.

The implementation of such a scheme should be technically achievable. However, a number of non-technical and logistical challenges will require careful consideration. As stated earlier, an administrative agency would be needed to calculate the Biojet Fuel Cost Differential in a clear and transparent fashion. The regional application of the scheme would need to be defined in order to assess the total number of service units. Currently EUROCONTROL provide forecasts for a number of regions.

The strengths of the proposed scheme as a way of covering the additional cost of biojet fuel use are as follows –

- Use of existing route charging infrastructure for covering the cost, based on an equitable measure of airline activity in the EU.

- Allows all airlines to effectively reduce the cost of the additional charge, by participating in the auction; this incentivises demand and helps develop supply capacity.

- Non-EU carriers can also participate in the auction, meaning that they can also reduce their costs. This could also apply to suppliers from outside the EU, so long as compliant with relevant sustainability criteria.

- Through the auction certification process, funds raised effectively get back to the suppliers. In addition, the auction provides an effective way of establishing a market price.

- The location of supply is effectively decoupled from demand location. Biojet fuel can be injected anywhere into the system once blending limits are respected. Airlines do not need to physically hold biojet fuel in their tanks, but need to hold certificates instead. This should allow for a cost effective market for biojet fuel to develop in locations that are most costs competitive.
The existing route scheme provides a framework and architecture for efficient recovery of charges for biojet fuel cost differential, however while leveraging the structure of the existing scheme could be beneficial there are a number of key challenges as follows:

- The introduction of a charging scheme for biojet fuel will have to be compatible with forthcoming ICAO MBM approach in 2020 which at the time of writing is yet unknown. Operationalization and implementation of a new scheme may take time and the integrity of a new scheme may be undermined if it is viewed as having a short life span.

- Similar to the existing route charging scheme this scheme does not allow for or consider the fuel efficiency of aircraft.

- The auction process is premised on meeting a Commission-stipulated level, increasing to 2 Mt by 2020. Therefore, the incentive structure of the route charging scheme need to be carefully considered so that airlines will participate in the auction and achieve the level necessary. Without this stipulation from the Commission to encourage airlines to take part, it is unlikely the scheme will work otherwise as there is no current economic advantage to using biojet fuel.

- The reputation of the existing route charging scheme could risk being compromised if the issue of biojet fuel recovery through the scheme is politicised.

- Interactions with the current ETS will have to be carefully considered.

- The scheme would increase complexity of the existing route charging scheme and add an administrative layer to the existing successful system.

- The scheme may require regulatory changes and may take time for operationalization.

- The scheme could lead to politicisation of the issue and resistance from industry if perceived to create distortions in the market.

EUROCONTROL note\(^{62}\) that while the modulation of charges to incentivize biojet fuels is important, they cite a number of concerns with the using route charges as a mean to promote biojet fuels including:

- Such as scheme may be outside the direct scope of the charging Regulation. The current wording covers more direct routings.

- Risk of diverse application by States. Would require regulatory changes to make it mandatory.

- Revenue neutral: cannot finance additional costs.

- Complexity: would increase complexity of the charging scheme

The Aviation industry operates on low margins and any extra costs, no matter how small, is sure to create a lot of debate. THE CRCO is very successful in recovering costs. The cost-effectiveness is

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\(^{62}\) Personal Communication. FlightPath Core team meeting, 13 May 2015
achieved by low collection costs of less than 0.3% and a high recovery rate of more than 99% of total amounts billed.

VIII.C.1. Potential Legal issues

Article 16 (b) of the regulations covering route charging states that Member States may modulate air navigation charges incurred by airspace users to reflect their efforts made in particular to reduce the environmental impact of flying. However, there are a number of principles and guidance that may also need to be considered prior to allowing for route charging to be used to increase biojet fuel uptake. The issues relate to the Rules and procedures of the Route Charges System, and include the following documents.

- Principles for Establishing the Cost-Base and the Unit Rates
- Guidance on the Rules and Procedures of the Route Charges System
- Conditions of Application of the Route Charges System and Conditions of Payment
- Financial Regulations applicable to the Route Charges System

These issues are presented in more detail below with making any judgment as to validity. It will be for the European Commission and EUROCONTROL to determine the legality of the scheme and the necessary changes or otherwise to the principles and guidance.

Principles for Establishing the Cost-Base and the Unit Rates

Article 2.2.1 states En route charges shall reflect the costs incurred either directly or indirectly in the provision of en route services, including the EUROCONTROL costs. The costs of en route services shall be financed by means of en route charges imposed on the users of en route services, and/or other revenues if appropriate without prejudice to the financing of exemptions of certain users of en route services through other sources of financing. Revenues derived through en route charges set in accordance with the Principles shall not be used to finance commercial activities of air navigation service providers.

Article 2.2.5 states Without prejudice to other sources of funding, part of the revenues resulting from en route charges may be used to fund common projects for network-related functions that are of particular importance for improving the overall performance of air traffic management and en route services in accordance with applicable law. In such cases, Contracting States shall put in place comprehensive and transparent accounting practices to ensure that users of en route services are not charged twice.

Article 3.4.2 states The modulation of charges shall not result in any overall change in revenue for the air navigation service provider. For Contracting States applying the determined cost method, over- or under recoveries shall be passed on to the following reference period. En route charges may also be modulated, on a non-discriminatory and transparent basis, to accelerate the deployment of new technologies. The modulation may in particular aim at giving incentives to equip aircraft with systems included in the common projects referred to in Paragraph 2.2.5.

The modulation of air navigation charges means a variation of the en route charge calculated on the basis of the provisions of Paragraph 3. Contracting States shall monitor the proper implementation
of the modulation of en route charges by air navigation service providers. The incentive scheme shall be limited in time, scope and amount. The estimated savings generated by the operational efficiency improvements shall at least offset the cost of the incentives within a reasonable timeframe. The scheme shall be subject to regular review involving airspace users’ representatives.

Guidance on the Rules and Procedures of the Route Charges System

Article 1.11 states that the role of the CRCO does not include: a. auditing the accounts of States / Air Navigation Service Providers (ANSPs); b. judging the cost-efficiency of States / ANSPs; c. target setting; d. enforcement of compliance with the Principles.

Conditions of Application of the Route Charges System and Conditions of Payment

Article 1 (4) states that the charges generated in a given charging zone may be subject to incentive scheme(s). EUROCONTROL may implement the incentive scheme(s) under the conditions and in accordance with the procedures agreed with the Contracting State(s) concerned.
IX. BIOFUEL OBLIGATIONS / MANDATE SCHEMES

An alternative option to increase the uptake of biojet fuel is to develop an EU level mandate that ensures 2020 objectives are met. In this section, we first describe how such mandates work at the Member State level under the RED, and then explore how a specific mandate on biojet could be applied at the EU level.

IX.A. Member State biofuel obligations

A number of EU Member States have implemented Biofuel obligation schemes to assist the goal of 10% RES-T under the RED. Member States choose to stimulate biofuel consumption by mandates, tax exemptions and subsidies, with a trend towards the first, and away from the latter. It is estimated that 6.6% of road transport energy is expected to be biodiesel in 2020, 2.2% to be bioethanol\(^{63}\) giving an estimated total of 8.8% for liquid biofuels in transport in 2020. Other biofuels and renewable electricity have much lower shares.

An example of an obligation scheme undertaken at the Member State level, in Ireland, is described in Box 5.

**Box 5: Biofuel obligation for road transport in Ireland**

Biofuels Obligation Certificates are awarded for the supply of one litre of sustainable biofuel. To incentivise the use of biofuels from wastes and residues, two certificates are awarded for each litre placed on the market. For other types of sustainable biofuel, one certificate is awarded for each litre. At the end of each year, fuel suppliers must have a certain percentage of certificates in proportion to the amount of petroleum based fuel placed on the market.

The average litre of biofuel placed on the market in Ireland in 2014 had a carbon intensity of c. 21.7 g CO\(_2\)eq / MJ, which represents a 74% reduction in carbon intensity in comparison to road transport fossil fuel. Based on the average biofuel carbon intensity, the substitution of fossil fuel with biofuel resulted in a reduction of c. 300 thousand tonnes of CO\(_2\)eq emissions. This equates to an overall saving of 2.4% in the GHG emissions from the road transport sector as a consequence of achieving a biofuel penetration rate of 3.98%, by volume\(^{64}\).

Monitoring and verification of such schemes is of utmost important. According to the RED, where biofuels and bioliquids are to be taken into account for renewable targets, Member States shall require economic operators to show that the sustainability criteria have been fulfilled. For that purpose, they shall require economic operators to use a mass balance system. The mass balance system links sustainability claims from the origin of the supply chain. The mass balance system means a system in which ‘sustainability characteristics’ remain assigned to ‘consignments’.

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\(^{64}\) National Oil Reserves Agency (NORA) website. [www.nora.ie/biofuels-obligation-scheme/administration.142.html](http://www.nora.ie/biofuels-obligation-scheme/administration.142.html)
A mass balance approach ensures producers purchase sufficient quantities of the feedstocks needed for a customer’s order and uses this material in its refining process. As a mix of different inputs is used, the physical product delivered to a customer may contain molecules from all the inputs used at a particular point in time. In essence, products with different properties can be physically mixed, but are kept administratively separated. Each element in the supply chain must keep track of the amount of product with certain characteristics it sources and sells. If there is a break in the chain, no claim can be made on the end product.

The future of Member State schemes obligation schemes could be uncertain, given that future RED proposals are unlikely to include a specific transport biofuel target. This is important because it could lead to a reduction in support for the biofuels industry, which will be critical to achieving an increase in biojet fuel. Of the current schemes in place, only the Netherlands have included biojet fuel (see Box 6 below). This is despite the current RED stating that all renewables used in all forms of transport should count towards the target (Article 3(4)). However, even if included, it is likely that road transport would see most biofuel uptake, due to the much lower cost differential between fossil and biofuels.

**Box 6: Inclusion of biojet in the Netherlands’s biofuel obligation scheme (Ecofys, 2013)**

The Netherlands have implemented a quota obligation for biofuel suppliers, starting from 4.25% in 2011 increasing to 5.5% in 2014. Oil product suppliers under the obligation can supply biofuels to the market themselves or arrange, through a ‘bioticketing’ process, for other specialist suppliers to sell into the market. For each unit of biofuel sold, a bioticket is issued, which can then be traded between obliged companies to fulfil their obligations. The value of a bioticket is currently established by the biodiesel market, as this is where most biofuels feed into the transport sector. Since December 2012, bio jet fuels have been able to contribute to the fulfilment of the obligation. Biojet suppliers e.g. SkyNRG can receive biotickets for the volume of bio jet fuel they sell, and can then sell these to oil suppliers that need (additional) biotickets to meet their obligation.

A number of high-level recommendations could be made to enhance the RED’s role in further incentivising the supply and use of biojet fuel.

- Encourage Member States to include biojet fuel within existing obligation schemes.
- Allow weightings to be assigned to biojet fuels to encourage uptake. This is already in place for some renewable sources.
- Developing a specific mandate for biojet fuel. As discussed above, simply including biojet in a broader transport fuel obligation may not be sufficient to increase uptake due to the cost advantage of biofuels for the road transport sector.

However, strong uncertainties remain as to the specific requirements of the post-2020 legislation, and whether there will be support explicitly for biofuels.

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IX.B. Developing an obligation / mandate scheme to deliver biojet fuel

A 2 Mt biojet fuel level by 2020 would require a mandate (expressed as a share) of approximately 3% for kerosene sold in Europe. Such a mandate would likely fall on fuel suppliers, who would pass on the increased costs to the airlines through the fuel prices. Airlines would then likely pass through the costs to passengers.

There are a number of considerations in design of the scheme:

**Obligated Party:** It is possible that mandates could be applied to fuel suppliers or to airlines. The challenge of imposing the obligation on airlines is that there are many compared to the number of fuel supplier. An advantage to placing the obligation on all suppliers in the EU is that it may help avoid the issue of ‘tankering’, where airlines could reduce costs by purchasing from fuel suppliers not subject to a biojet fuel obligation; however this may happen if airlines are flying from outside the EU.

Crucially a mandate applied at the EU level would allow for a level playing field for airlines operating in the EU. The introduction of a stronger mandate in one Member State might lead to competitive impacts for airlines based in that country. However, there are likely to be some distortionary impacts on airlines based in the EU who operate outside of the EU, with higher fuel costs than for non-EU competing airlines. For low cost airlines that only operate within the EU, there is likely to be less distortionary impacts as all intra-EU airlines will be subject to the same fuel costs.

**Options for compliance.** There is also the question of compliance. A flexible scheme that allowed for trade in certificates (such as in the Dutch or RFS2 case) would allow some fuel suppliers to purchase certificates rather than actually supply biojet fuel physically. Additional flexibility could also be built in that allowed for certificate issued under RED (from biojet fuel supply) to count against obligations under other specific mandates. Such linkages could also be explored with the RFS2, as it is conceivable that the same suppliers either operate or will in the future in both markets.
An administrative body would need to monitor the mandate across suppliers, and provide certification based on the biojet fuel supplied. This certification process, in line with changes to RED, would need to differentiate biojet fuel supplied based on the feedstock used; for biojet fuel produced from wastes and residues, this could gain double the number of certificates thus encouraging the industry to exploit these more sustainable feedstocks. The administrating body would ensure that obligated parties surrendered sufficient certificates to match their obligation.

A snapshot of the implications of such an obligation scheme is explained here. As per Section VII, it is assumed for the purpose of demonstration that the cost differential between biojet fuel and kerosene is approximately 0.50€/L. This gives a current cost of 1.3€b for the Biojet Fuel Cost Differential. If this is equalised across EU 28 projected sales of jet kerosene in 2020 (54.4 Mtoe), it would introduce a charge of an extra 0.02€/L of kerosene.

While the additional cost, expressed in this way, seems relatively low, tight operating margins mean that this can have an impact on airline profitability. If passed through to customers, it is likely that resulting demand response to price will have an impact (although this study has not considered the price impacts on airline profits). For long haul operators, distortionary effects could be seen if non-EU operators are not subject to similar price impacts.

The other costs of implementation not considered below include costs of infrastructure to blend, deliver and supply biojet, and the costs of administrating such a scheme.

In summary, there are some strengths of such a proposal but also some challenges to implementation. Strengths include -
Similar schemes exist in many Member States, with non-EU experience also through RFS2.

The scheme guarantees that the target is met, which can be verified based on the mass balance approach.

EU wide mandate provides a level playing field for EU only operators, removing any variation in Member State implementation.

Challenges to implementation include –

- Distortionary impacts for EU carriers operating outside of the EU.
- Risks of ‘tankering’ by airlines refuelling outside of EU.
- Getting infrastructure in place at airports to allow for biojet to be fed in – although this applies to other mechanisms.
- Setting up of administrative capacity to operate the scheme.
- There is a question as to how this may or may not be supported under post-2020 legislation, if broader legislative certainty is withdrawn from the biofuels industry.
X. INDUSTRY-BASED AND VOLUNTARY APPROACHES TO INCREASING BIOFUEL TAKE-UP

One option for meeting the biojet fuel cost differential could be pursued on a voluntary basis, by the airline industry, through a measure akin to an existing offset scheme. This would be a scheme that allowed an additional payment to be added during the ticket booking process, or through partnership with corporations; rather than the revenues going to offsetting projects, they could be used directly to fund the biofuel used.

One such scheme exists, run by KLM and SkyNRG, called the Corporate BioFuel Programme. It was set up to help meet the target of 1% of all KLM flights being powered by biofuel in 2015, and is part of a strategy to reduce its CO₂ emission by 20% in 2020. Corporations, of which there are 20 participating, pay a surcharge to meet the difference between kerosene and biofuels. Participants who take part in the scheme make a payment to ensure that a fixed percentage of their flights are taken on aircraft using biofuel; this percentage can also be linked to a specific route.

X.A. Current offset schemes

Such schemes allow individuals or organisations to neutralise or offset the emissions associated with their flight by investing in carbon reduction projects. According to IATA, 30 member airlines run offset programmes. IATA has published guidance on setting up offset programmes. There are many different schemes including KLM’s CO2ZERO compensation service, and Virgin Atlantic offsetting programme. Schemes are set-up differently, based on whether to link the payment to the emissions associated with the flight or simply to donate to an offset programme without making this link. Payment may be based on an opt-in approach, be mandatory, and / or be payable via air miles schemes. BA stopped using such a scheme in 2011, opting for a Customer Carbon Fund that put money into UK-based projects, and due to the introduction of the EU ETS. Limited data appear to be available concerning the uptake of offset schemes, suggesting potentially limited traction. Studies suggest the uptake is generally low; a CAA survey stated that only 7% of air passangers were using some sort of offset.

The previous section on MBM suggests that the costs of offsets are much lower than the cost differential between jet kerosene and biojet. Therefore, using an offset type scheme to help fund biojet uptake is unlikely to succeed. Given the significantly higher costs associated with biojet, we have considered whether passengers would be willing to pay via voluntary passenger surcharges that might cover such costs.

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**X.B. Willingness to pay (WTP) for offsetting**

Brouwer et al. (2008) set out to determine whether air travel passengers are supportive of measures that increase the cost of travel and compensate the damage caused by their flights, and to quantify the benefits they obtain from mitigating emissions. They determined that the main motivation is from a recognition of responsibility and accountability for climate change as well as the genuine belief in the detrimental effects of climate change on future generations as opposed to raising money for good causes (as per offset projects). Awareness and WTP (based on contingent valuation approach) is highest among European and lowest in USA and Asian travellers. However it should be borne in mind that WTP is what air travel passengers say they would willing to pay and this may not actually translate in payments.

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean WTP per flight (€)</th>
<th>Mean WTP per t CO$_2$ (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>26.6</td>
<td>41</td>
</tr>
<tr>
<td>USA</td>
<td>20.2</td>
<td>17.1</td>
</tr>
<tr>
<td>Asia</td>
<td>16.1</td>
<td>10</td>
</tr>
<tr>
<td>All</td>
<td>23.1</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 8. Levels of willingness to pay for different regions

Interestingly, €41 is much higher than most schemes charge for offsetting e.g. €2-18 but is along way short of meeting the type of emissions tax needed to bridge the above value.

Lu & Shon (2012) also used a contingent valuation approach to assess WTP amongst Taiwanese passengers. Passengers flying to China, Northeast Asia, Southeast Asia, and western countries are willing to pay $5.0, $8.8, $10.8, and $28.6 for the offset [these broadly translate into $/t CO$_2$ values of $20-25]. This accounts for 1% and 1.5% of travel cost. Passengers’ WTP for the carbon-offsets increase with the increase in the cost of air travel - a 1% increase in the travel cost results in 0.38% increase in the WTP. Business travellers are willing to pay more for the offsets (compared to leisure passengers) if their employers or others subsidize their travel costs, but if they fly in economy class they wish to pay less. The analysis also finds that if people know nothing about the scheme, or believe it is ineffective, they are willing to pay less for the offsets. However, if they believe the scheme results in large emissions reductions they will pay more. They also respond more positively if reducing aviation emissions is seen to be shouldered by both the passengers and the airlines.

Cheung et al. (2015) find that WTP values vary greatly depending on the description of the type of offset. There are also a range of socio-economic characteristics that lead to much higher WTP e.g.

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higher paying respondents below. On the whole, forest protection projects are much higher than the current offset price e.g. offered by Quantas of $5 to about $30.

Finally, MacKerron et al. (2009) suggests that uptake of voluntary offsets may be encouraged by investing in projects with co-benefits and by emphasising those co-benefits to consumers.\textsuperscript{76} In addition, certification regimes add value to offsets, helping compensate for increased costs, provided that consumers are made fully aware of them. WTP for a VCO was estimated at approximately £24 per person per flight, similar to that found by Brouwer et al. 2008. Certification was seen to be an important factor in WTP, while biodiversity was the most important co-benefit. On co-benefits, when all three were presented (biodiversity, human development, and low-carbon market/technology development), the overall WTP was higher.

**X.C. Alternative Proposal**

While voluntary approaches may have limited potential, they can be tailored or modified to provide important signals from governments and industry leaders. One such approach could be for the European Commission to mandate that all flights on official Commission business, including flights paid for under H2020 or other research type funding make a contribution to a biojet fuel fund. The level of any such funding would be small but the gesture would provide an important top-down message that leadership in this area is important. For simplicity, a flat fee could be charged to reduce administrative burden. While the Commission does not publish a detailed breakdown on travel cost, if 20,000 flights per year are captured it would generate €200,000, which could be diverted to research in this area. Again the objective of such a scheme is not necessarily to raise substantial funds for biojet fuel; the objective is to raise awareness of the issue and the environment opportunity that biojet fuel may present.

XI. **Integration of Biojet Fuel with other EU Strategies**

Like many areas of energy and climate policy, biojet fuel policy has multiple stakeholders and linkages across a wide range of existing and proposed EU strategies. For greater policy cohesion, it is recommended that biojet fuel be considered and integrated into the following EU strategies. Synergies with other Commission initiatives is important and the need to better involved stakeholders and ensure multidisciplinarity is an accepted *modus operandi* of Commission’s work.

**XI.A. Bioeconomy Strategy**

In 2012 Europe’s Bioeconomy Strategy\(^77\) was launched and adopted. While it is a new piece of legislation, it aims to focus Europe’s common efforts in the area of bioenergy structured around 3 pillars of research, policy and competitiveness. While currently there is no focus of the role of bioenergy for biojet fuels in this strategy, given the uses of common feedstock, engagement with this strategy is recommended.

**XI.B. Circular Economy Strategy**

The European Commission adopted an ambitious Circular Economy Package\(^78\), which includes revised legislative proposals on waste to stimulate Europe’s transition towards a circular economy. This will have important relevance for feedstocks and feedstock competition for biojet fuel. Approaches to waste managements targets within the strategy are line with the objectives of the Bioeconomy Strategy aiming at using bio-waste streams as resources.

**XI.C. Aviation Strategy**

In December 2015, the European Commission adopted a new Aviation Strategy\(^79\) for Europe with the objective to boost Europe’s economy, strengthen its industrial base and contribute to the EU global leadership. While the strategy acknowledges the challenge of emissions reduction, there is no specific mention of the possible role of biojet fuels.

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XII. DISCUSSION AND CONCLUSIONS

The creation of a biojet fuel industry either in Europe or at a global level is a key pathway to meaningful long term decarbonisation for the aviation industry. The question on how to stimulate this industry is one that is of great importance. At an international level the latency of international policy making on emissions reduction in aviation must be acknowledged. The introduction of a market-based mechanism is unlikely to stimulate the growth of a biojet fuel industry in the short to medium term and initiatives to grow and kick-start the industry need to be explored today, given that any new scheme may require regulatory changes and will take time for operationalization.

A number of key points can be taken from this analysis.

From the Commission’s perspective

- Transport in general has expensive GHG mitigation options. The pull effect of renewable targets could reduce this by creating demand for renewable technologies and establishing scale. Clarification is required on renewable transport legislation post 2020.
- Sequencing of policy is crucial for market confidence. Sustainability criteria should be resolved to send market signal for correct feedstocks. This includes greater clarification on the issue of ILUC and sustainability criteria.
- Member States should be encouraged to recognise biojet fuel for RES-T in their domestic implementation.
- The Commission should explore taking a top-down leadership approach by mandating that all flights required for Commission business and research make a contribution to a biojet fuel fund.
- Great integration of biojet fuel policy with current strategies on bioeconomy, Aviation and Circular economy is needed.
- Explore options to allow weightings to be assigned to biojet fuels to encourage uptake through the existing RED. This is already in place for some renewable sources.

In relation to the biojet fuel cost recovery through route charges:

The existing route scheme provides a framework and architecture for efficient recovery of charges for biojet fuel cost differential, however while leveraging the structure of the existing scheme could be beneficial there are a number of key challenges as follows:

- The introduction of a charging scheme for biojet fuel will have to be compatible with the forthcoming ICAO MBM approach in 2020. Operationalization and implementation of a new scheme may take time and the integrity of a new scheme may be undermined if it is viewed as having a short life span.
- The reputation of the existing route charging scheme could risk being compromised if the issue of biojet fuel recovery through the scheme is politicised.
• Similar to the existing route charging scheme this scheme does not allow for or consider the efficiency of aircraft engines.

• The auction process is premised on meeting a Commission-stipulated level, increasing to 2 Mt by 2020. Therefore, the incentive structure of the route charging scheme need to be carefully considered so that airlines will participate in the auction and achieve the level necessary. Without this stipulation from the Commission to encourage airlines to take part, it is unlikely the scheme will work otherwise as there is no current economic advantage to using biojet fuel.