BECOOL
Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

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Norms and standards for advanced biofuels	
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1. Introduction

The entire set of activities of the BECOOL project is actually strongly related to the EU legislative framework on advanced biofuels. The present deliverable addresses the normative framework surrounding the use of advanced lignocellulosic biofuels, and the economic, social, and regulatory implications of their large-scale utilisation.

The report briefly investigates the structure of the legislation, with a special focus on the aviation sector.

The document focuses on the just-released RED2, the new normative framework covering the period from 2020 to 2030. Following the EU Parliament and Council votes (end of November 2018 and beginning of December 2018, respectively) the following main elements are now set in the new Directive, published on the 21st of December 2019 in the EU Official Journal L328:

- advanced biofuels mandate at 3.5%, with Advanced Biofuels double counted;
- introduction of High ILUC and low ILUC risk concepts;
- extension to RFNBO (Renewable Fuel of Non-Biological Origin) and Recycled Carbon Fuels;
- aviation and maritime counted 1.2 times.

Feedstocks cannot be removed from Annex IX part A (Advanced Biofuels), but it is possible to add other sustainable feedstocks on the list (upon request to EC – procedure still to be defined).

The new Directiverequires the EC to elaborate delegated acts and implementing acts. One of the first delegated act (on low- and high-ILUC risk biofuels) is due by the end of February 2019. Member States will have 18 months to incorporate REDII into their national regulations.

The entire set of activities of the BECOOL project are actually strongly dependent on the EU legislative framework on advanced biofuels. The present deliverable provides the normative framework surrounding the use of advanced lignocellulosic biofuels, and the economic, social, and regulatory implications of their large-scale utilisation.

The report briefly investigates the previous structure, with a special focus on the aviation sector.

The aim of the document is then dedicated to just-released RED2, the new normative framework in the period from 2020 to 2030. Following the EU Parliament and Council votes (end of November 2018 and beginning of December 2018, respectively) the following main elements are now set in the new Directive, published on the 21st of December 2019 in the EU Official Journal L328:

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2. Definitions

BIOFUELS: means liquid fuel for transport produced from biomass

BIOJET FUEL: a jet fuel derived from biomass

BIOMASS: means the biodegradable fraction of products, waste and residues from biological origin from agriculture, including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin.

BIOMASS FUELS: means gaseous and solid fuels produced from biomass

DROP-IN FUELS: A fuel that can be used at any blend level with current engine technology and does not require modifications to aircraft engines and fuel systems and ground supply infrastructure.

EU ETS: European Union Emission Trading Scheme

FOOD AND FEED CROPS: means starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land

HIGH ILUC: The contribution of biofuels produced from “high indirect land-use change” feedstocks towards this target is limited to 2019 consumption levels in each EU Member State, phasing down to zero by 2030.

HYDROPROCESSING: Generic term used to describe a range of refinery processes that use hydrogen, along with an appropriate catalyst, to remove undesired components from refinery streams. The technology is core to a modern petrochemical refinery.

ILUC: indirect land-use change, occurs when the increased demand for feedstocks leads to agricultural expansion and the conversion of natural lands.

LCA: Life Cycle Assessment accounts the inflows and outflows “from cradle to grave”: this is from the extraction, manufacturing, consumption, recycling to the finale disposal.

LIGNO-CELLULOSIC MATERIAL: material composed of lignin, cellulose and hemicellulose, such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes

LOW ILUC: Biofuels certified as being produced from “low indirect land-use change” feedstocks are exempt from this limitation.

NON-FOOD CELLULOSIC MATERIAL: feedstock mainly composed of cellulose and hemicellulose, and having a lower lignin content than ligno-cellulosic material, including food and feed crop residues, cover crops before

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and after main crops, industrial residues, including from food and feed crops after vegetal oils, sugars, starches and protein have been extracted and material from biowaste.

RECYCLED CARBON FUELS: means liquid and gaseous fuels that are produced from liquid or solid waste streams of non-renewable origin which are not suitable for material recovery in accordance with Article 4 of Directive 2008/98/EC, or from waste processing gas and exhaust gas of non-renewable origin which are produced as an unavoidable and unintentional consequence of the production process in industrial installations

RED: The Renewable Energy Directive establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

RED2: The Renewable Energy Directive 2 recasts and eventually repeals the previous RED, introducing new targets towards 2030.

RFNBO: Renewable Fuel of Non-Biological Origin, means liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass

UCO: Used Cooking Oil. Also referred to throughout the literature as WVO (waste vegetable oil) and UVO (used vegetable oil), RVO (recycled vegetable oil) and RCO (Recycled Cooking Oil). UCO has been chosen as the standard for this document.

3. Glossary

ASTM American Society for Testing and Materials

CORSIA Carbon Offsetting and Reduction Scheme for International Aviation

EU ETS European Union Emission Trading System

EUA EU Allowances

EUAA EU Aviation Allowances

FQD Fuel Quality Directive

FRL Fuel Readiness Level

GHG Green House Gas

ICAO International Civil Aviation Organization

ILUC Indirect Land Use Change

LDC Least Developed Countries

LLDC Landlocked Developing Countries

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LUC	Land Use Change
LULUCF	Land Use, Land-Use Change and Forestry
MS	Member State
MVR	Monitor, Verify and Report
RED	Renewable Energy Directive
RES	Renewable Energy Source
RFNBO	Renewable Fuel of Non-Biological Origin
RTK	Revenue Tonne Kilometres
SAF	Sustainable Aviation Fuel
SIDS	Small Island Developing States
TRL	Technology Readiness Level

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4. Previous EU normative framework

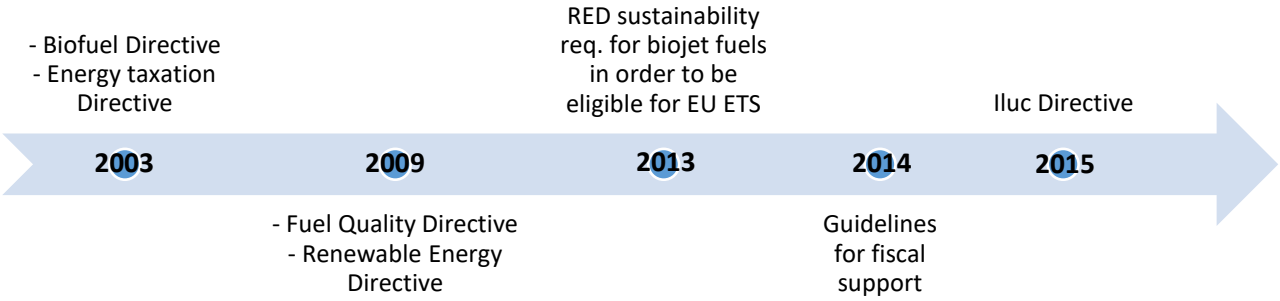

Figure 1: EU Normative Framework timeline (2003-2015)

This section reviews the policy measures and legislative acts that have been implemented at the EU level before the final RED II Directive publishing and which directly influence the advanced lignocellulosic biofuels sector. Below, we will briefly summarize their main policy goals; an extended evaluation will be performed for selected ones in the following parts of this chapter.

1. **Biofuel Directive (2003/30/EC):** It introduced a non-mandatory 5.75% target for biofuels in the transportation sector, to be achieved by 2010, eventually by blending with fossil fuels.
2. **Energy Taxation Directive (2003/96/EC):** regarding state aids for environmental protection and energy, it implemented:
    - Excise duty reduction/exemption upon the European Commission's approval
    - Direct subsidies to biofuels plants
3. **RED Directive (2009/28/EC):** successively amended by **2015/1513 "ILUC" Directive**, it introduced:
    - a 10% target for renewable energy in transportation to be achieved in 2020,
    - a 7% cap on the share of biofuels produced from food and other land-based crops (to count toward the 10% renewable energy share),
    - a double counting for advanced biofuels (listed in Annex IX, Part A) and used cooking oil and animal fat (listed in Annex IX, Part B)
    - a 0.5% flexible target for advanced biofuels (listed in Annex IX, Part A)
4. **Fuel Quality Directive (2009/30/EC):** successively amended by 2015/1513 "ILUC" Directive, it introduced:
    - 6% lifecycle GHG emission-reduction target from energy used in transportation sector to be achieved by 2020, with reference to 2010 levels
5. **Guidelines for Fiscal Support (2014):** they introduced several changes in fiscal support:
    - Limiting fiscal support options to food-based biofuels
    - Prohibiting direct subsidies or tax benefits for new food-based biofuel capacity.
    - Stopping fiscal support to existing food-based biofuels installation in 2020.
6. **EU direct grant programs** for demonstration of AAF technologies at large scale, such as FP7, Horizon 2020, NER 300

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4.1. RED Directive (after 2015/1513 ILUC Directive amendment)

In 2009 it set in *Art.3, par.4* a mandatory 10% renewable energy share target for the energy consumed by transportation for all Member States, to be achieved by 2020; moreover, it set in *Art.3, par.1*, a 20% renewable energy share target for total energy consumption at EU level.

For the calculation of the contributions to the 10% target coming from specific renewable energy sources, a 2x multiplier has been defined for biofuels produced from feedstocks listed in Annex IX[1] (*Art.3, par.4,f, as amended in 2015/1513 ILUC Directive*).

In order to reduce ILUC impacts, a cap on biofuels produced from food or other land-based crops[2] has been set: they shall be no more than 7 % of the final consumption of energy in transport in the Member States in 2020. Moreover, a non-binding target of 0.5% in energy content of the share of energy from renewable sources in all forms of transport in 2020 has been proposed to each MS; it has to be met with biofuels produced from feedstock listed in Annex IX part A, as well as from other feedstock, determined to be wastes, residues, non-food cellulosic material or ligno-cellulosic material by the competent national authorities and already used in existing installations (*Art.3, par.4,d, as amended in 2015/1513 ILUC Directive*).

Art. 5 states that biofuels and bioliquids have to fulfil the sustainability criteria set out in *Art. 17, par. 2 to 6*, in order to be taken into account for the calculation of the share of energy from renewable sources; those criteria are listed below:

- GHG emission savings[3]:
  - Installations in operation before October 2015: at least 35% until 31/12/2017, then at least 50%
  - Installations starting operations after October 2015: at least 60%
- Raw materials not obtained from land with high biodiversity value (in or after January 2008):
  - primary forest and other wooded land
  - area designated for the protection of rare, threatened or endangered ecosystems
  - highly biodiverse grassland
- Raw materials not obtained from land with high carbon stock (in or after January 2008):
  - wetlands
  - continuously forested areas
  - land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10 % and 30 %
- Raw materials not obtained from land that was peatland in January 2008
- For agricultural raw materials cultivated in the Community: shall be obtained in accordance with part A and in point 9 of Annex II to Council Regulation (EC) No 73/2009 of 19 January 2009, and in accordance with the minimum requirements for good agricultural and environmental condition defined pursuant to Article 6(1) of that Regulation.

[1] The complete annex, with the list of feedstocks eligible for double counting, is reported in Chapter 8.1

[2] Cereal and other starch-rich crops, sugars and oil crops and from crops grown as main crops primarily for energy purposes on agricultural land

[3] Art. 19, together with Annex V, set the procedures fit GHG savings calculation.

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Biofuels have to comply with this list of criteria irrespectively of whether the raw materials were cultivated inside or outside the territory of the Community; if produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues, they need only fulfil the GHG savings criterium.

The *2015/1513 ILUC Directive* amendment introduced reporting of ILUC emissions, but not its accounting when assessing the GHG performance of biofuel pathways against the required GHG savings threshold in the RED. This could allow food-based biofuels to still qualify under the GHG reduction threshold if they offer relatively high direct carbon savings from feedstock and fuel production, process, and transport.

4.2. Fuel Quality Directive (after 2015/1513 ILUC Directive amendment)

Art. 7,a introduced a mandatory target for fuel suppliers to reduce lifecycle GHG emissions by 6% for energy supplied for transportation in the year 2020, with reference to 2010 levels. This target is expected to be largely met with first-generation biofuels, together with electricity and upstream emission reductions (UERs) from petroleum production, such as venting and flaring reductions at oil drilling sites.

This scenario, together with the decision not to include ILUC accounting (such as in the RED Directive) negatively affects the incentive in the FQD to consume Advanced Bio-fuels (1); anyway, blending constraints for ethanol and biodiesel may limit the use of first-generation biofuels.

4.3. Aviation Focus

Nevertheless, the large-scale deployment of sustainable biofuels in air transport had been slow down by inadequate policies and regulations (2). The Renewable Energy Directive (Directive 2009/28/EC on the promotion of the use of energy from renewable sources) set up the objective of 10% of renewable energy consumption in transport in 2020, promoting the use of biofuels (through the double counting mechanism), but in rail and road sector only. The strong effort towards the production of sustainable biofuels endorse the terrestrial transport sector, following a limited access for air transport to renewable sources (3).

Moreover, the aviation industry is bounded to a long-term infrastructure, as well as to airplanes which will fly on hydrocarbon type fuels for the coming decades. In a short-term framework, Sustainable Aviation Fuel (SAF) is the only significant solution; SAF is a so-called drop-in fuel, made from certified sustainable biomass (sustainability criteria are set out in *Art. 17, par. 2 to 6,* of RED Directive). Although technology has been proven to work, there is currently limited activity in the production and use of SAF; the main reason is related to the price gap between fossil jet fuels and SAF.

The existing EU legislation provides an opportunity to cover at least a part of this price gap through an amendment to RED Directive, made in 2015 by ILUC Directive, to recognise the possibility of a so-called ‘voluntary aviation opt-in’ to implement in Member States legislation:

"In the case of suppliers of biofuels in aviation, Member States may permit such suppliers to choose to become contributors to the reduction obligation provided that those biofuels comply with the sustainability criteria"

Up to this date, this voluntary opt-in was taken up by the Netherlands and he UK.

As an example, the Netherlands has obligated road transport fuels suppliers, under the RED, to supply a certain percentage of their fuels from renewable sources; this obligation is checked with certificates – called HBEs – issued by the Dutch Emission Authority (NEA). HBEs can be generated also by the producers of Sustainable Aviation Fuels (SAF), when supplying them to the Dutch market. Since no obligation is set for the

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aviation sector, the HBEs can be sold to the road transport obligated parties, thus enabling the voluntary aviation opt-in. This way, the price premium between conventional jet fuels and SAF can partly be covered.

As all member states have implemented the RED differently, not all member states will have the same opportunities of implementing the voluntary aviation opt-in. A 2016 study commissioned by SkyNRG to the University of Utrecht (4) has categorized the 28 EU member states through their potential of implementing the voluntary aviation opt-in. The main criteria used by the study are listed below, in order of importance:

- Existence of a certificate system
- Existence of other policy incentives, such as tax exempt on road biofuels
- Existence of a local sustainable aviation fuel development opportunity

This results in six high potential member states which basically are the ones where a tradable certificate system is already in place for road biofuels, since it is crucial for a quick and easy implementation of the voluntary aviation opt-in: Germany, Ireland, Italy, Portugal, Spain and United Kingdom.

5. RED II Directive (2018/2001)

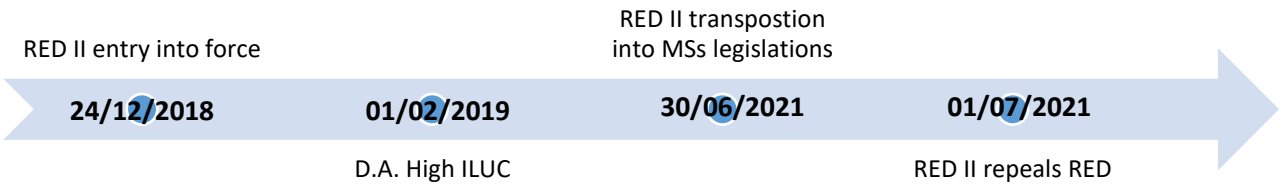

Figure 2: RED II Implementation Timeline

Directive 2018/2001 (RED II Directive) entered into force on 24/12/2018 and will repeal Directive 2009/28/EC (RED Directive) with effect from 1 July 2021, as stated by Art. 37; Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with Directive 2018/2001 by 30 June 2021 (Art. 36).

5.1. Overall Targets and Biofuels contribution to the Transport Sector Target

RED II Directive set two binding targets in Art.3:

- the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 must be at least 32 % by 2030
- the share of renewable energy within the final consumption of energy in the transport sector must be at least 14 % by 2030

Regarding the overall final energy consumption target, from January 1st, 2021, the share of energy from renewable sources in each Member State shall not be lower than the baseline shown in Annex I, Part A, that is equal to the 2020 target set in RED Directive. Moreover, the gross final consumption of energy from renewable sources in each Member State will be calculated as the sum of:

- gross final consumption of electricity from renewable sources

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- gross final consumption of energy from renewable sources in the heating and cooling sector
- final consumption of energy from renewable sources in the transport sector

For the purposes of the last point, biofuels, biomass fuels and renewable liquid and gaseous transport fuels of non-biological origin (RFNBO) consumed in the transport sector will be taken into account. RFNBO will also be considered for the first point but only for the calculation of total electricity from RES produced in a MS (Art 7).

For the calculation of the transport sector target, RFNBO must be taken into account by MSs, also when they are used as intermediate products for the production of conventional fuels; recycled carbon fuels may be taken into account.

The contribution of advanced biofuels and biogas (produced from the feedstock listed in Annex IX, Part A) to the transport sector target is set to be at least 0.2 % in 2022, at least 1 % in 2025 and at least 3.5 % in 2030.

The share of biofuels, bioliquids, and biomass fuels produced from food and feed crops and consumed in a MS in the transport sector shall be no more than one percentage point higher than their share in the road and rail transport sectors in 2020, with a cap of 7 % in the road and rail transport sectors energy consumption. Where that share is below 1 %, it may be increased to a maximum of 2 %.

MSs may set a lower limit and may distinguish, for the purposes of sustainability criteria (Art. 29), between different biofuels, bioliquids and biomass fuels produced from food and feed crops, taking into account best available evidence on their ILUC impact.

For the calculation of both targets for a MS, the share of high ILUC-risk biofuels, bioliquids or biomass fuels produced from food and feed crops shall not exceed the level of consumption registered in that MS in 2019, unless they are certified to be low ILUC risk. Moreover, between December 31st, 2023 and December 31st, 2030 they have to be phased out completely from the calculation.

The following Table 1 considers all the possible contribution to the transport sector target, taking into account eventual upper or lower limits, multipliers and other information where provided.

Table 1: Recap of all possible contributions in term of fuel/feedstock to the transport sector target

Type of fuel	Percentage of Contribution	Possible Multipliers	Notes
Feedstocks from Annex IX, Part A (Advanced Biofuels)	• ≥ 0.2 % in 2022 • ≥ 1 % in 2025 • ≥ 3.5 % in 2030	2x	
Feedstocks from Annex IX, Part B	≤1 .7 %*	2x	*: of the energy content of transport fuels supplied for consumption or use on the market
Food/Feed Feedstock Biofuels	The lower between: • ≤ (2020 value + 1%) • ≤ 7%	no	MSs may set a lower limit and may distinguish between different biofuels, bioliquids and biomass fuels produced from food and feed crops
High ILUC-risk feedstock Biofuels	• Before 31/21/2023: ≤ (2019 value)	no	

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	• Between 31/21/23 and 31/12/30: go to 0%		
Renewable Electricity (road and Rail)	not set	• road:4x • rail: 1.5x	
Aviation and Maritime Fuels	not set	1.2x	exception of fuels produced from food and feed crops
RFNBO	not set	*	See description in Chapter 5.2
Recycled Carbon Fuels	not set	*	

*: a D.A. establishing a Union methodology has to be set up

By 1 February 2019, the Commission shall submit a report on the status of worldwide production expansion of the relevant food and feed crops, as well as adopt a delegated act setting out the criteria for certification of low ILUC-risk biofuels, bioliquids and biomass fuels and for determining the high ILUC-risk feedstock. Both the report and the delegated act shall be based on the best available scientific data.

By 1 September 2023, the Commission shall review the criteria laid down in the above-mentioned delegated act to amend such criteria, where appropriate, and to include a trajectory to gradually decrease the contribution to the RES share targets of high ILUC-risk biofuels, bioliquids and biomass fuels. In 2023 the Commission is also asked to assess the target obligations, with a view to submitting, a legislative proposal to increase them in the event of:

- substantial costs reductions in the production of renewable energy
- the need to meet the Union's international commitments for decarbonisation
- a significant decrease in energy consumption in the Union.

Each MS is also enforced to set an obligation on fuel suppliers, together with an indicative trajectory, to ensure that the share of renewable energy in 2030 will reach the proposed target. Anyway, a degree of flexibility is given to MSs, so that they can exempt different fuel suppliers and different energy carriers, in order to take into account the varying degrees of maturity and the cost of different technologies. Finally, MSs may exempt fuel suppliers supplying fuel in the form of electricity or RFNBO from the requirement to comply with the minimum share of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX with respect to those fuels.

5.2. Calculation rules regarding the minimum shares of renewable energy in the transport sector

Art. 27 defines that, for the calculation of the transport sector target, all types of energy from renewable sources, including renewable electricity supplied to the road and rail transport sectors, shall be taken into account. MSs may also take into account recycled carbon fuels; finally, the share of biofuels and biogas produced from the feedstock listed in Annex IX, Part B shall be limited to 1.7 % of the energy content of transport fuels supplied for consumption or use on the market.

For the purposes of demonstrating compliance with the 14% target sector target, a set of energy multiplier have been put into force:

- biofuels and biogas for transport produced from the feedstock listed in Annex IX may be considered to be twice their energy content

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- renewable electricity shall be considered to be four times its energy content when supplied to road vehicles and may be considered to be 1.5 times its energy content when supplied to rail transport
- the share of fuels supplied in the aviation and maritime sectors shall be considered to be 1.2 times their energy content, with the exception of fuels produced from food and feed crops.

For the purposes of this paragraph, when electricity is used for the production of RFNBO, either directly or for the production of intermediate products, there are three possibilities to determine the share of renewable energy.

- For electricity that has been taken from the grid:
  - It can be counted as the average share of electricity from RES in the country of production is used, as measured two years before the year in question
  - It can be counted as fully renewable if it is produced exclusively from renewable sources (and it can be demonstrated), ensuring that its renewable properties are claimed only once and only in one end-use sector
- For electricity obtained from direct connection to an installation generating renewable electricity, it may be fully counted as renewable, provided that the installation:
  - comes into operation after, or at the same time as, the installation producing the RFNBO
  - is not connected to the grid or is connected to the grid but evidence can be provided that the electricity concerned has been supplied without taking electricity from the grid.

By December 31st, 2021, the Commission shall adopt a delegated act establishing a Union methodology setting out detailed rules by which economic operators are to comply with the requirements laid down in the above-mentioned situation.

5.3. Sustainability and GHG emissions saving criteria for biofuels, bioliquids and biomass fuels

Similarly to the 2020 RED and FQD, the RED II defines a series of sustainability and GHG emission criteria that liquid biofuels and bioliquids used in transport must comply with in order to:

- be counted towards the overall RES target
- be counted toward the transport sector RES target and obligations
- to be eligible for financial support by public authorities.

Those criteria, reported below, are laid down in Art. 29, paragraphs 2 to 7 and 10 and shall be applied irrespectively of the geographical origin of the biomass. However, some exemptions and different request in terms of compliance with the set of criteria have been laid down in the Art. 29 and are reported at the end of this chapter.

Par. 2: Biofuels, bioliquids and biomass fuels produced from waste and residues derived from agricultural land shall be taken into account only where operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon.

Par. 3: Biofuels, bioliquids and biomass fuels from agricultural biomass should comply with the following land criteria and thus not be produced from raw materials originating from High Biodiversity land (as of January 2008), including;

- Primary forests

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- Area designated for nature protection or for the protection of rare and endangered ecosystems or species
- Highly biodiverse grasslands of more than 1 ha

Par. 4: Biofuels, bioliquids and biomass fuels from agricultural biomass should comply with the following land criteria and thus not be produced from raw materials originating from High Carbon stock land that changed use after January 2008 from one of the following categories:

- Wetlands
- Continuously forested land
- Other forested areas with trees higher than five meters and canopy cover between 10% and 30%.

Par. 5: Biofuels, bioliquids and biomass fuels from agricultural biomass should comply with the following land criteria and thus not be produced from raw materials originating from land that was peatland in January 2008.

Par. 6: Biofuels, bioliquids and biomass fuels produced from forest biomass shall meet the following criteria to minimise the risk of using forest biomass derived from unsustainable production:

- The harvesting should take place with legal permits
- the harvesting level does not exceed the growth rate of the forest
- and that forest regeneration takes place
- areas of high conservation value, such as wetlands and peatlands, must be protected
- the impacts of forest operations on soil and biodiversity should be minimized.

Par. 7: Biofuels, bioliquids and biomass fuels produced from forest biomass shall meet the following land-use, land-use change and forestry (LULUCF) criteria:

- the country of origin of the biomass feedstock must be signatory of the Paris Agreement
- the country of origin must have submitted a Nationally Determined Contribution to the United Nations Framework Convention on Climate Change (UNFCCC) covering emissions and removals from LULUCF sector and showing emissions do not exceed removals
- the country of origin has a national system in place for accounting for LULUCF emissions and removals in accordance with the requirements in the Paris agreement.

The criteria defined in par. 7 must be applied either at the country level or at forest sourcing area level.

The Commission will define implementation guidelines for par. 6 and 7 by 31 January 2021, adopting an Implementing Act. Moreover, the Commission shall assess whether the criteria laid down in par. 6 and 7 effectively address LULUCF criteria and shall, if appropriate, submit a legislative proposal to amend those paragraphs for the period after 2030.

Par. 10: The required GHG emission savings for transport biofuels and bioenergy are listed in following Table 2.

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Table 2: GHG savings

Valid for plants entering into operation	Transport biofuels, biogas and bioliquids	Transport RFNBO	Recycled Carbon Fuels
Before 5/10/2015	50%	*	*
From 6/10/2015 to 31/12/2020	60%	*	*
From 1/1/2021	65%	70%	#

*: No mandatory GHG savings threshold until 2021

#: By 1/1/2021, the Commission shall adopt a delegated act establishing appropriate minimum thresholds for GHG emissions savings of recycled carbon fuels

Biomass fuels shall fulfil criteria only if used in installations producing electricity, heating and cooling or fuels with a total rated thermal input of:

- 20 MW or more in the case of solid biomass fuels
- 2 MW or more in the case of gaseous biomass fuels

Anyway, MSs may apply the sustainability and greenhouse gas emissions saving criteria to installations with lower total rated thermal input.

Biofuels, bioliquids and biomass fuels produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues, are required to fulfil only the greenhouse gas emissions saving criteria in order to be taken into account for the purposes of this chapter. This also apply to waste and residues that are first processed into a product before being further processed into biofuels, bioliquids and biomass fuels.

MSs may establish additional sustainability criteria for biomass fuels; in this case, the Commission shall assess the impact of such criteria on the internal market by December 31st, 2026 and, if necessary, define a proposal to ensure harmonisation.

5.4. Verification of compliance with sustainability and GHG criteria and calculation of GHG impacts of biofuels

Where biofuels, bioliquids and biomass fuels, or other fuels that are eligible for counting towards the renewable energy share target in transport, MSs shall require economic operators to show that the sustainability and GHG emissions saving criteria have been fulfilled. For those purposes, they shall require economic operators to use a mass balance system which shall ensure that each consignment is counted only once for the purposes of calculating the gross final consumption of energy from renewable sources and shall include information on whether support has been provided for the production of that consignment, and if so, on the type of support scheme.

In order to ensure that compliance with the sustainability and GHG emissions saving criteria as well as with the provisions on low or high direct and indirect LUC-risk biofuels, bioliquids and biomass fuels is verified and in particular to prevent fraud, the Commission shall adopt implementing acts specifying detailed implementing rules, including adequate standards of reliability, transparency and independent auditing and require all voluntary schemes to apply those standards.

GHG emissions saving from the use of biofuel, bioliquids and biomass fuels shall be calculated in one of the following ways:

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- by using a default value for GHG saving when it is set, for a specific production pathway, in Part A or B of Annex V (for biofuels and bioliquids) and in Part A of Annex VI (for biomass fuels) and when annualised emissions from carbon stock changes caused by LUC, calculated in accordance with Part B of Annex VI (for biomass fuels) or Part C of Annex V (for biofuels and bioliquids) is equal or lower than zero.
- by using an actual value calculated in accordance with the methodology laid down in Part C of Annex V (for biofuels and bioliquids) and in Part B of Annex VI (for biomass fuels)
- by using a value calculated as the sum of the factors of the formulas referred to in point 1 of Part C of Annex V, where disaggregated default values in Part D or E of Annex V may be used for some factors, and actual values, calculated in accordance with the methodology laid down in Part C of Annex V, are used for all other factors (for biofuels and bioliquids)
- by using a value calculated as the sum of the factors of the formulas referred to in point 1 of Part B of Annex VI, where disaggregated default values in Part C of Annex VI may be used for some factors, and actual values, calculated in accordance with the methodology laid down in Part B of Annex VI, are used for all other factors (for biomass fuels)

Member States may submit to the Commission reports including information on the typical GHG emissions from the cultivation of agricultural raw materials of the areas on their territory, together with a description of the method and data sources used to calculate the level of emissions. In the case of territories outside the Union, equivalent reports drawn up by competent bodies may be submitted to the Commission.

The Commission may, by means of implementing acts, decide that those reports contain accurate data that may be used instead of the disaggregated default values for cultivation laid down in Part D or E of Annex V for biofuels and bioliquids and in Part C of Annex VI for biomass fuels, in the areas included in such reports.

The Commission is empowered to adopt delegated acts to amend, where appropriate, Annexes V and VI by adding or revising the default values or modifying the methodology.

In order to ensure the uniform application of Part C of Annex V and Part B of Annex VI, the Commission may adopt implementing acts setting out detailed technical specifications including definitions, conversion factors, the calculation of annual cultivation emissions or emission savings caused by changes above and below-ground carbon stocks on already cultivated land, the calculation of emission savings from CO2 capture, CO2 replacement and CO2 geological storage.

5.5. Annex V and VI analysis

Annex V is dedicated to biofuels and bioliquids (actual and future technologies, where future technologies is referred to the ones that were not on the market or were on the market only in negligible quantities in 2016) while Annex VI is dedicated to biomass fuels.

Both have a common structure, where in the first part typical and default GHG emissions saving values are defined as percentage values, for several production pathways. The following section is dedicated to the methodology for the calculation of GHG emissions and GHG emissions savings using disaggregated values. The last section contains disaggregated default and typical GHG emissions values for biofuels, bioliquids and biomass fuels.

Focusing on transport fuels, biofuels and bioliquids, GHG emissions from the production and use shall be calculated as follows:

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$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

where

- E = total emissions from the use of the fuel;
- e_{ec} = emissions from the extraction or cultivation of raw materials;
- e_l = annualised emissions from carbon stock changes caused by land-use change;
- e_p = emissions from processing;
- e_{td} = emissions from transport and distribution;
- e_u = emissions from the fuel in use;
- e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;
- e_{ccs} = emission savings from CO2 capture and geological storage; and
- e_{ccr} = emission savings from CO2 capture and replacement.

GHG emissions from biofuels, E, shall be expressed in terms of g CO2eq/MJ.

Annualised emissions from carbon stock changes caused by land-use change, el, shall be calculated by dividing total emissions equally over 20 years. For the calculation of those emissions, the following rule shall be applied:

$$e_l = (CS_R - CS_A) * 3.664 * \frac{1}{20} * \frac{1}{P} - e_B$$

where

- e_l = annualised greenhouse gas emissions from carbon stock change due to land-use change (measured as g CO2eq/MJ). 'Cropland' and 'perennial cropland'[4] shall be regarded as one land use
- CS_R = the carbon stock per unit area associated with the reference land-use (measured as mass (tonnes) of carbon per unit area, including both soil and vegetation). The reference land-use shall be the land-use in
- January 2008 or 20 years before the raw material was obtained, whichever was the later
- CS_A = the carbon stock per unit area associated with the actual land-use (measured as mass (tonnes) of carbon
- per unit area, including both soil and vegetation). In cases where the carbon stock accumulates over more than one year, the value attributed to CSA shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever the earlier;
- P = the productivity of the crop (measured as biofuel or bioliquid energy per unit area per year)
- e_B = bonus[5] of 29 g CO2eq/MJ for biofuel or bioliquid if biomass is obtained from restored degraded land under the following conditions:
    - the land was not in use for agriculture or any other activity in January 2008

[4] Perennial crops are defined as multi-annual crops, the stem of which is usually not annually harvested such as short rotation coppice and oil palm

[5] The bonus of 29 g CO2eq/MJ shall apply for a period of up to 20 years from the date of conversion of the land to agricultural use, provided that a steady increase in carbon stocks as well as a sizable reduction in erosion phenomena for severely degraded land are ensured.

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- is severely degraded land[6], including such land that was formerly in agricultural use.

The Commission shall review, by 31 December 2020, guidelines for the calculation of land carbon stocks.

Where a fuel production process produces, in combination, the fuel for which emissions are being calculated and one or more other products (co-products), greenhouse gas emissions shall be divided between the fuel or its intermediate product and the co-products in proportion to their energy content.

In the case of biofuels and bioliquids, all co-products shall be taken into account for the purposes of that calculation. No emissions shall be allocated to wastes and residues. Co-products that have a negative energy content shall be considered to have an energy content of zero for the purposes of the calculation.

Wastes and residues, including tree tops and branches, straw, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined) and bagasse, shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product.

For biofuels, for the purposes of the calculation referred to in point 3, the fossil fuel comparator EF(t) shall be 94 g CO2eq/MJ.

5.6. Delegated Acts and Implementing Acts

In Table 3 below a brief description of the D.A. and I.A. of interest can be found, together with Article of reference, empowerment deadline and release deadline, where specified.

Table 3: Deadlines for D.A. and I.A. of interest

Description	Type	Art.	Date
Establishing appropriate minimum thresholds for greenhouse gas emissions savings of recycled carbon fuels through a life-cycle assessment that takes into account the specificities of each fuel.	D.A.	25 (2)	01/01/2021 up to 24/12/2023
Setting out the criteria for certification of low indirect land-use change-risk biofuels, bioliquids and biomass fuels and for determining the high indirect land-use change-risk feedstock for which a significant expansion of the production area into land with high-carbon stock is observed	D.A.	26 (2)	01/02/2019 up to 24/12/2023
Adapting the energy content of transport fuels, as set out in Annex III, in accordance with scientific and technical progress.	D.A.	27 (1,c)	up to 24/12/2023
Specifying the methodology to determine the share of biofuel, and biogas for transport, resulting from biomass being processed with fossil fuels in a common process	D.A.	28 (5)	31/12/2021 up to 24/12/2023
Specifying the methodology for assessing GHG emissions savings from RFNBO and from recycled carbon fuels, which shall ensure that credit for avoided emissions is not given for CO2 the capture of which has already received an emission credit under other provisions of law.	D.A.	28 (5)	31/12/2021 up to 24/12/2023
Amend the list of feedstocks set out in Parts A and B of Annex IX by adding, but not removing, feedstock.	D.A.	28 (6)	25/6/2019 and every two years, up to 24/12/2023

[6]a land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.

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Further specifying the criteria by which to determine which grassland are to be covered by point (d) of Art 29	I.A.	29 (3)	not specified
Establishing the operational guidance on the evidence for demonstrating compliance with the criteria laid down in paragraphs 6 and 7 of Art. 29	I.A.	29 (8)	31/01/2021
Specifying detailed implementing rules, including adequate standards of reliability, transparency and independent auditing and require all voluntary schemes to apply those standards in order to ensure the compliance with the sustainability and GHG emissions saving criteria as well as with the provisions on low or high direct and indirect LUC-risk biofuels, bioliquids and biomass fuels.	I.A.	30 (8)	not specified
Use data from MSs reports instead of the disaggregated default values for cultivation laid down in Part D or E of Annex V for biofuels and bioliquids and in Part C of Annex VI for biomass fuels, in the areas included in such reports.	I.A.	31 (4)	not specified
Amend, where appropriate, Annexes V and VI by adding or revising the default values or modifying the methodology	D.A.	31 (5)	Up to 24/12/2023
Setting out detailed technical specifications including definitions, conversion factors, the calculation of annual cultivation emissions or emission savings caused by changes above and below-ground carbon stocks on already cultivated land, the calculation of emission savings from CO2 capture, CO2 replacement and CO2 geological storage	I.A.	31 (6)	not specified

6. Aviation Focus

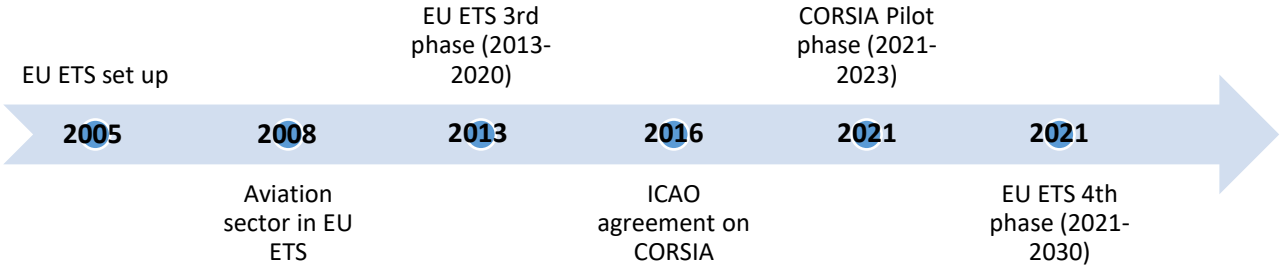

Figure 3: Aviation sector, market-based measures timeline

Along with legislative measures, market-based measures such as EU ETS and ICAO CORSIA are being put into operation. Emissions trading systems (such as EU ETS) and offsetting schemes (such as CORSIA) both address aviation emissions but differ in their functioning. ETSs generally work towards economy-wide emission reduction targets, while offsetting schemes also compensate for emissions by reductions in other sectors but without an associated cap[7].

6.1. EU-Emission Trading System

The EU-ETS is the EU's key tool for reducing, in a cost-effective manner, greenhouse gas emissions from the power and heat, industry and aviation sectors. Set up in 2005, it is world's first major carbon market and still remains the biggest one.

[7] European Aviation Environmental Report 2019 - EASA - ISBN 978-92-9210-214-2

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The system covers, for CO_2 emissions, the following sectors:

- power and heat generation
- energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals
- commercial Aviation (since 2008)

The EU ETS use the 'cap and trade' principle: a cap is set on the total amount of certain GHG that can be emitted by installations covered by the system. The cap is reduced over time in order to drive total emissions to reduction. Within the cap, companies receive or buy emission allowances, tradable with one another as needed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs, or else sell them to another company that is short of allowances. Finally, a limited amount of international credits from emission-saving projects around the world can be bought by companies. After each year a company must surrender enough allowances to cover all its emissions, otherwise fines are imposed.

For the aviation sector, the initial scope of the EU ETS covered all flights arriving at, and departing from, airports in the European Economic Area; from 2013, however, flights to and from airports in non-European Economic Area countries have been excluded until the end of 2023. This exclusion was made to facilitate negotiation of a global market-based measure for international aviation emissions at the International Civil Aviation Organization (ICAO). As a consequence, at present only flights between airports located in the European Economic Area are included in the EU ETS.

EU ETS has gone under several different period, current phase is the 3rd, covering 2013-2020 period. The cap for aviation activities for the current phase of the ETS was set to 95% of 2004-2006 aviation emissions.

Since 2013, the amount of annual EU Aviation Allowances (EUAAs) issued is around 37.5 Mt (1 EUAA or EUA equals 1 tonne of CO2). The EUAAs cover emissions under the EU ETS cap for aviation. About 15% of these allowances are auctioned, while 85% are allocated for free. For CO2 emissions exceeding the EU ETS aviation cap, aircraft operators must purchase EU Allowances from the stationary sectors; on the contrary, stationary installations are not permitted to use aviation allowances for compliance. In addition, aircraft operators could use international credits for up to 15% of their verified emissions in 2012. Since 2013, each aircraft operator is entitled to use international credits up to a maximum of 1.5% of its verified emissions during the current phase, in addition to any residual entitlement from 2012.

In 2017, 677 operators, which included more than 200 non-European carriers, operated under the scope of the system. EU ETS carbon prices varied between €4 and €6 per tonne of CO2 during the 2013-2017 period. For 2017, it is estimated that these EUA-related costs represent about 0.3% of total operating costs for aircraft operators on flights within the scope of the EU ETS. As of September 2018, EU Allowances representing one tonne of CO2 were being traded at over €20.

For the 4th phase of the EU ETS, from 2021 to 2030, the system will see several modifications that will also affect the aviation sector. The linear reduction factor of 2.2% per year will also be applied to the aviation cap. Emission reductions will have to be exclusively domestic; therefore, only EU Aviation Allowances (EUAAs) and EU Allowances (EUAs) will be eligible for compliance.

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The 2017 revision to the EU ETS Directive includes a mandate from the European Parliament and the Council to the Commission to consider ways for CORSIA to be implemented in the EU through a revision of the Directive, consistent with the EU 2030 climate objectives.

6.2. ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

In October 2016, the 39th General Assembly of ICAO Contracting adopted Resolution A39-3 [81], aiming to introduce a global market-based measure in order to offset international aviation's CO2 emissions above 2020 levels through international credits, namely the 'Carbon Offsetting and Reduction Scheme for International Aviation' (CORSIA) (5). In June 2018, the ICAO Council approved the associated Standards and Recommended Practices (SARPs). Work is continuing on the additional rules on eligible fuels and emission units that can be used to comply with CORSIA offsetting requirements.

CORSIA first action will be defining a CO2 emission baseline, to be used as a reference after 2020. In order to do so, all aeroplane operators with international flights producing annual CO2 emissions greater than 10,000 tonnes from aeroplanes with a maximum take-off mass greater than 5,700 kg will be required to monitor, verify and report their CO2 emissions during 2019 and 2020. The average yearly CO2 emissions reported during that period will represent the baseline; beyond 2020, the aviation sector will be required to offset its international CO2 emissions above this level.

76 States have officially notified ICAO that they intend to voluntarily participate in the pilot and first phase of CORSIA, representing approximately 76% of international aviation activity in terms of Revenue Tonne Kilometres (RTKs). The first deadline for intention notification is set to 30 June 2020.

CORSIA comprises of three implementation phases:

- the pilot phase (2021-2023)
- a first phase (2024-2026)
- a second phase (2027-2035).

During the pilot phase and first phase, offsetting requirements will only be applicable to flights between States that have volunteered to participate. The second phase will apply to all ICAO Member States within the agreed applicability scope, complying with some requirements:

- individual share of international aviation activities in RTKs over 0.5% of total RTKs in year 2018
- being part of the list of States that account for 90% of total RTKs when sorted starting from the highest amount of individual RTKs
- not being part of Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Landlocked Developing Countries (LLDCs).

Each international flight within the scope of CORSIA is attributed to an aeroplane operator; each aeroplane operator is attributed to a State to which it must submit an Emissions Monitoring Plan. Aeroplane operators monitor, verify and report (MVR) their fuel use according to the approved plan; their annual emissions offsetting requirements are calculated by the State (see Figure 4).

Emissions monitoring applies to all flights, including those not subject to offsetting requirements. Offsetting requirements are calculated taking into account the growth of the aviation sector and that of an individual aeroplane operator (6).

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Aeroplane operators meet their offsetting requirements on a 3-year compliance period basis by purchasing and cancelling CORSIA eligible emissions units. Aeroplane operators can reduce their offsetting requirements by using CORSIA eligible fuels that meet CORSIA sustainability criteria.

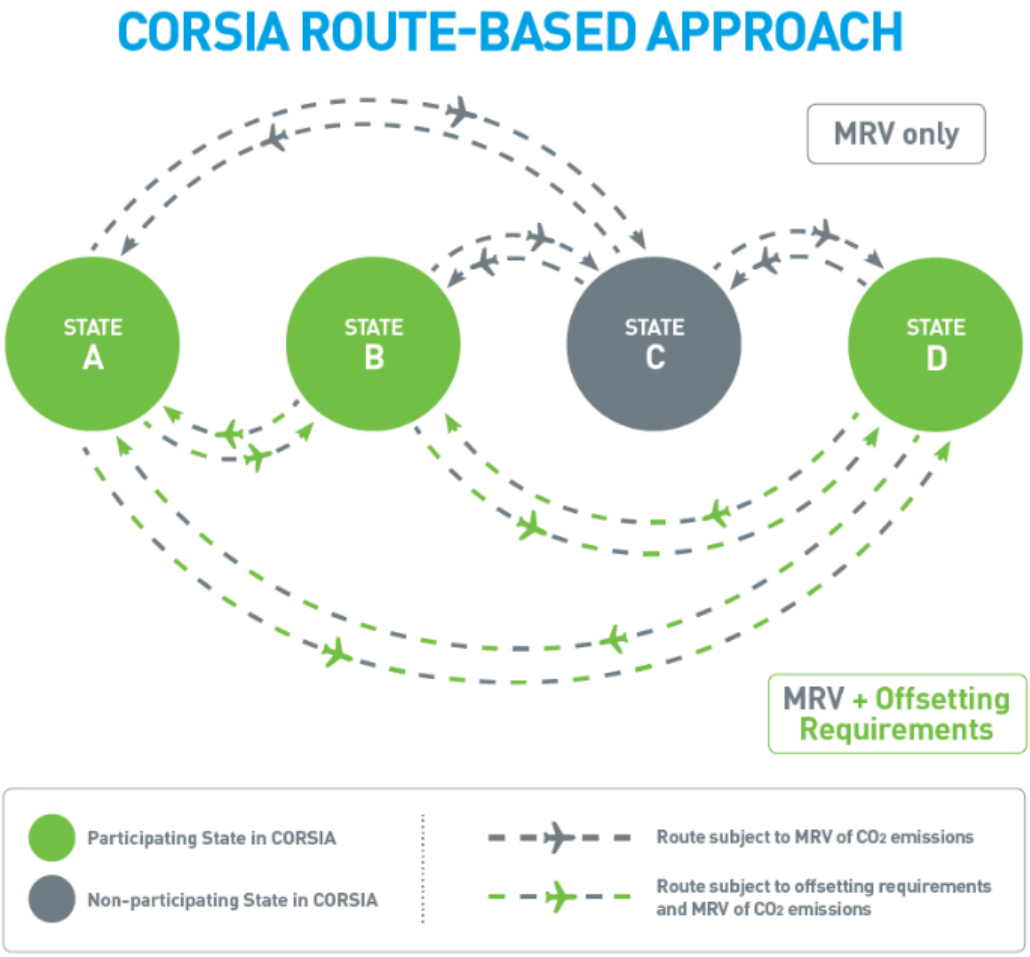

Figure 4: Explanation of CORSIA MRV and offsetting requirements (taken from ICAO website)

7. Standards

This document focuses un Aviation Standards, according to task 3.1 of Work Program.

7.1. Aviation

In commercial aviation the JET-A1 (i.e. the conventional fossil aviation fuel) is regulated by several specifications and recommended practices for its use.

Among these:

- ASTM D1655 "Standard Specification for Aviation Turbine Fuel" (US and international)
- UK Defence Standard 91-91 "Turbine Fuel, Aviation Kerosene Type, Jet A-1" (UK and international)

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- Joint Inspection Group (JIG) Aviation Fuel Quality Requirements for Jointly Operated Systems (AFQRJOS, or "joint checklist" – international)
- GOST 10227 TS-1 (Russia and CIS)
- Number 3 Jet Fuel (China)
- Others, produced by organizations (engine manufacturers, pipeline operators, etc.) wishing to define fuel to their own requirements

This list contains very similar specification since they essentially describe the same product. For istance, ASTM D1655 and Def Stan 91-91 have nearly identical requirements for Jet A-1 with just an exception in acidity level, and a parameter related to naphthalene content.

ASTM D1655, in particular is the main standard for conventional jet fuel and it has been modified numerous times since it was first released to reflect changes in quality requirements associated with engine and aircraft modifications and new materials. In 2009, ASTM International approved D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, the first specification describing a jet fuel not derived from petroleum crude. New renewable fuels must be certified and approved by D7566, which defines the composition and properties of renewable aviation fuels. In order to proceed with the certification process, ASTM D4054 standard is a guidance for a new fuel or additive approval process that includes the prerequisite testing and required interactions with the engine and airframe manufacturers, standards organizations and airworthiness agencies such as the FAA and EASA. In particular the ASTM D7566 norm allows for blending up a defined quantity of renewable jet fuel in the standard Jet A-1, already reported in chapter 8.2.

8. Annexes

8.1. RED – Annex IX

RED	**RED II**
Part A. Feedstocks and fuels, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:	**Part A.** Feedstocks for the production of biogas for transport and advanced biofuels, the contribution of which towards the minimum shares referred to in the first and fourth subparagraphs of Article 25(1) may be considered to be twice their energy content:
(a) Algae if cultivated on land in ponds or photobioreactors.	(a) Algae if cultivated on land in ponds or photobioreactors;
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC.	(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC;
(c) Bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to	(c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households

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separate collection as defined in Article 3(11) of that Directive.	subject to separate collection as defined in point (11) of Article 3 of that Directive;
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex.	(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex;
(e) Straw	(e) Straw;
(f) Animal manure and sewage sludge.	(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches.	(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch.	(h) Tall oil pitch;
(i) Crude glycerine.	(i) Crude glycerine;
(j) Bagasse.	(j) Bagasse;
(k) Grape marcs and wine lees.	(k) Grape marcs and wine lees;
(l) Nut shells.	(l) Nut shells;
(m) Husks.	(m) Husks;
(n) Cobs cleaned of kernels of corn.	(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, i.e. bark, branches, precommercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil.	(o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, precommercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;
(p) Other non-food cellulosic material as defined in point (s) of the second paragraph of Article 2.	(p) Other non-food cellulosic material;
(q) Other ligno-cellulosic material as defined in point (r) of the second paragraph of Article 2 except saw logs and veneer logs.	(q) Other ligno-cellulosic material except saw logs and veneer logs.
(r) Renewable liquid and gaseous transport fuels of non-biological origin.	

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(s) Carbon capture and utilisation for transport purposes, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.	
(t) Bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.	
Part B. Feedstocks, the contribution of which towards the target referred to in the first subparagraph of Article 3(4) shall be considered to be twice their energy content:	**Part B.** Feedstocks for the production of biofuels and biogas for transport, the contribution of which towards the minimum share established in the first subparagraph of Article 25(1) shall be limited and may be considered to be twice their energy content:
(a) Used cooking oil.	(a) Used cooking oil;
(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009 of the European Parliament and of the Council	(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.

8.2. SAF Production pathways & GHG reductions

ASTM-Approved Production Pathways

The American Society for Testing and Materials (ASTM) International has developed standards to approve new bio-based aviation fuels, and currently six production pathways have been certified for blending with conventional aviation fuel. These include:

- **FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene):** Biomass is converted to synthetic gas and then into bio-based aviation fuel. Maximum blending ratio is 50%.
- **FT-SPK/A is a variation of FT-SPK**: where alkylation of light aromatics creates a hydrocarbon blend that includes aromatic compounds. Maximum blending ratio is 50%.
- **HEFA (Hydroprocessed Fatty Acid Esters and Free Fatty Acid):** Lipid feedstocks, such as vegetable oils, used cooking oils, tallow, etc. are converted using hydrogen into green diesel, and this can be further separated to obtain bio-based aviation fuel. Maximum blending ratio is 50%.
- **HFS-SIP (Hydroprocessing of Fermented Sugars - Synthetic Iso-Paraffinic kerosene):** Using modified yeasts, sugars are converted to hydrocarbons. Maximum blending ratio is 10%.
- **ATJ-SPK (Alcohol-to-Jet Synthetic Paraffinic Kerosene)**: Dehydration, oligomerization and hydroprocessing are used to convert alcohols, such as iso-butanol, into hydrocarbon. Maximum blending ratio is 50%.
- **Co-processing:** Biocrude up to 5% by volume of lipidic feedstock in petroleum refinery processes.

Additional pathways are currently in the ASTM certification process.

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Alongside the technology readiness, the commercial development of a certain fuel could be different due to various other drivers (e.g. certification issues, costs issues). To better clarify the progress of a specific fuel production pathway towards full commercialisation, the US Commercial Aviation Alternative Fuels Initiative has developed the Fuel Readiness Level (FRL) system, which has been endorsed by ICAO.

Process		Technology Readiness Level (TRL)	Fuel Readiness Level (FRL)
Fischer-Tropsch Synthetic Paraffinic Kerosene	*FT-SPK*	6-8	7
Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics	*FT-SPK/A*	6-7	7
Hydroprocessed Fatty Acid Esters and Free Fatty Acid	*HEFA*	9	9
Hydroprocessing of Fermented Sugars - Synthetic Iso-Paraffinic kerosene	*HFS-SIP*	7-8	5-7
Alcohol-to-Jet Synthetic Paraffinic Kerosene	*ATJ-SPK*	6-7	7
Co-processing biocrude up to 5% by volume of lipidic feedstock in petroleum refinery processes	*Co-processing*	7-8	6-7

Figure 5: TRL and FRL of ASTM certified production pathway for use in commercial flights (7)

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