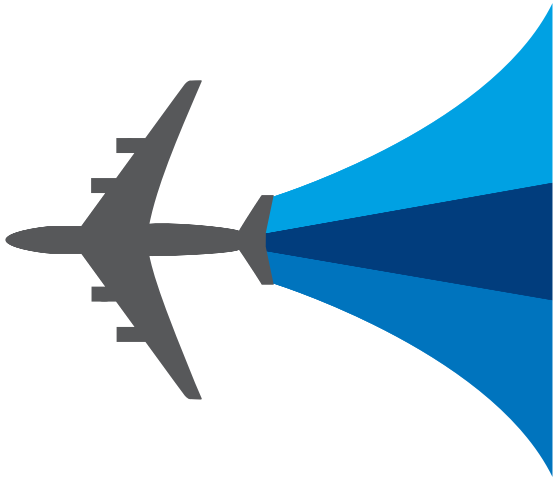

PART I

INTRODUCTION AND CONTEXT

2 GOALS AND DESIRES TO THE NEW AVIATION INDUSTRY

Augusto Barbosa Cortez [et al.]. "Goals and desires to the new aviation industry", p.29-36. In: Luís Augusto Barbosa Cortez (Editor). **Roadmap for sustainable aviation biofuels for Brazil — A Flightpath to Aviation Biofuels in Brazil**, São Paulo: Editora Edgard Blücher, 2014.
http://dx.doi.org/10.5151/BlucherOA-Roadmap-002

2 GOALS AND DESIRES TO THE NEW AVIATION INDUSTRY

2.1 Vision

The aviation industry worldwide has demonstrated a strong desire to participate in a global effort to mitigate GHG emissions and, therefore, is deeply committed to reduce CO_2 emissions. The present goal is towards Carbon Neutral Growth (CNG) by 2020 and 50% reduction in net CO_2 emissions over 2005 levels by 2050 (**Figure 6**). Several actions are being taken by the aviation industry to meet this goal. Among them are more efficient use of fuels with improved engines, lighter airplane design, aerodynamic improvements, advanced airspace management, and lower carbon fuels.

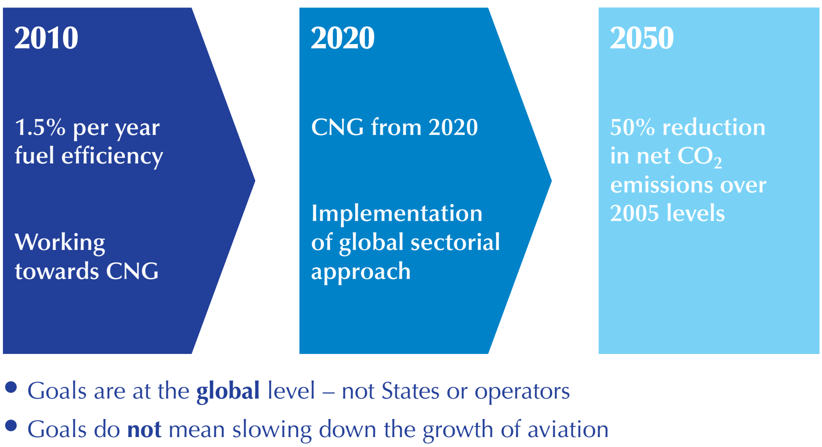

Figure 6 Expected targets for CO_2 emissions by the aviation industry for 2010, 2020 and 2050 (CNG – carbon neutral growth). Source: Freire, 2011.

During the 1st Sustainable Aviation Biofuels for Brazil Project Workshop, it became clear to the participants that the aviation industry stakeholders do not believe that trading carbon credits should be a solution to reduce CO_2 emissions over the long term. It is recognized that the key opportunity to achieve the goal is to use sustainable biofuels in substitution to aviation kerosene, which can effectively help reduce GHG emissions.

The aviation industry wishes to develop sustainable "drop-in biofuels," meaning it equals all performance characteristics of fossil fuel. While not yet cost competitive, drop-in jet biofuel has been demonstrated with a number of tests and commercial (revenue generating) flights by airlines. Work to drive costs down to competitive levels is under way in many parts of the world. Important challenges include scaling up combined feedstock and refining technology pathways, and improvements in logistic & deployment characteristics in a way that biofuel applications become economically viable.

Concerning the sustainability aspects of biofuels, it is recognized that "*not all bio-energy is sustainable energy*" (MCFARLANE, 2012) and, as a consequence, bio-derived jet fuel should be developed using strong sustainability criteria and verification to meet the needs of the aviation industry.

According to Mcfarlane (2012), the aviation industry needs to prioritize second and third generation biofuels that meet rigorous sustainability criteria. He added "Don't reinvent the wheel – use developed sustainability criteria in the analysis" (*ibid*). SAFN used Roundtable on Sustainable Biomaterials criteria as screening tool to evaluate feedstock paths and potential issues.

Concerning sustainability criteria to compare different biofuels, Nassar and Cantarella (2012a) presented some key issues concerning biofuels strengths and weaknesses (**Table 3**). Some feedstocks have more mature agronomic experience, while others have good potential, but not necessary results from large scale production. At this point, no alternative can be excluded based on these arguments, a statement broadly praised by the participants of the 1st Sustainable Aviation Biofuels for Brazil Project Workshop.

Table 3 Key issues on biomass availability: different feedstocks (NASSAR; CANTARELLA 2012a).

	WIDESPREAD FEEDSTOCK	ENERGY DEDICATED (NON FOOD) FEEDSTOCKS
Strengths	• Sugarcane, vegetable oils (soybean, rapeseed, palm, etc.), sources of cellulose (sugarcane bagasse and planted forest) • Already available • Strong accumulated knowledge • Established production practices • Availability of varieties for different climate conditions: temperature but, more important, tropical conditions • Strong research base: food market	• Jatropha, carmelina, energy cane, etc. • Do not compete directly with food: if marginal land is used, or as a second crop (second crops are possible in tropical or subtropical areas) • Great potencial torpidly increasing yields (lower technology start level)
Weaknesses	• Food versus fuel debate • Land use issues • Food market (demand) as the driver for pricing: drives price up • Need to achieve above yields increase trends • Strong correlation with the energy market (fertilizers)	• Are even more expensive and economics are not well known yet • Are not available in large scale • Very restricted availability of varieties and technological packages • Restricted knowledge on plant behavior and physiology under field conditions • No or limited mechanization of cropping and harvesting • Marginal land

Throughout the 1st workshop, the audience was presented to a preliminary vision for the Technology Road Map (TRM) process. The presented vision of this Project was:

"The aviation industry will have, in the next 20-40 years, a transition towards the use of sustainable biofuels in substitution of petroleum based jet fuels. The use of biofuels in aviation will have to be effective, efficient, and advantageous from the environmental, social and economic points of view, in order to consolidate the expansion of the aviation industry worldwide."

The roadmapping methodology implemented in this project aimed to reach a consensus on R&D priorities (gaps and barriers) in order to promote the use of sustainable biofuels for aviation. The entire roadmapping process involves, after the kick-off meeting (1st workshop), the presentation of all view-points, dialog, thoughtful action, favorable ground-work (**Figure 7**). "With all this done, it will have a higher chance of success" (LYONS, 2012).

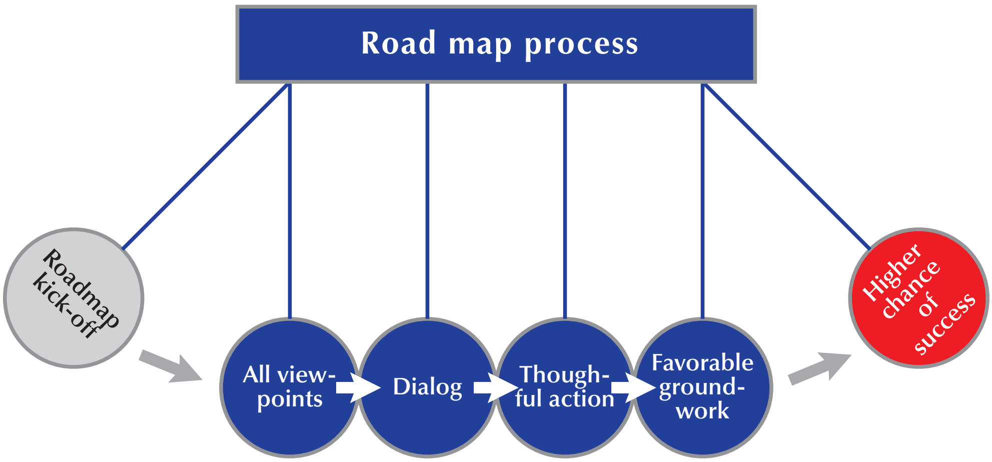

Figure 7 Steps involved in the roadmapping process. Source: Boeing apud Lyons, 2012.

In the breakout session, the participants were divided into four groups to discuss the proposed vision (related to mitigate CO_2 emissions by the aviation industry) and goals (socio-economic, costs and environment). There was a general consensus that the vision proposed by the aviation industry represents a logic target to be followed. Ultimately, the main goals are:

1. Carbon Neutral Growth from 2020;
2. 50% reduction in net CO_2 emissions by 2050 over 2005 levels.

The "environmental, social and economic points of view" for using biofuels in "effective, efficient and advantageous" way demanded further developments throughout the workshop. The participants were presented to the following goals:

1. Social goal:
   - Improve regional development; the goal is to have a positive impact on rural development where the feedstock is being produced

2. Economic goal:
   - Reduce production costs; the goal is that biofuels for aviation should not have a high production cost than regular fossil jet fuel
3. Environmental goal:
   - Produce Environmentally Sustainable Biofuels; the goal is to produce biofuels for aviation in an environmentally sustainable way.

The goals to "reduce production costs" and "produce an environment sustainable biofuel" were seen without criticism as natural objectives. However, the socio-economic target ("improve rural development") seemed not be very clear, was considered too broad and beyond the scope of this project. The consensus was that the impacts caused by the feedstock production, considering it to be rural, should either improve local working conditions or the wealth generated or both.

Figure 8 presents the roadmap targets discussed and agreed in the Roadmapping process.

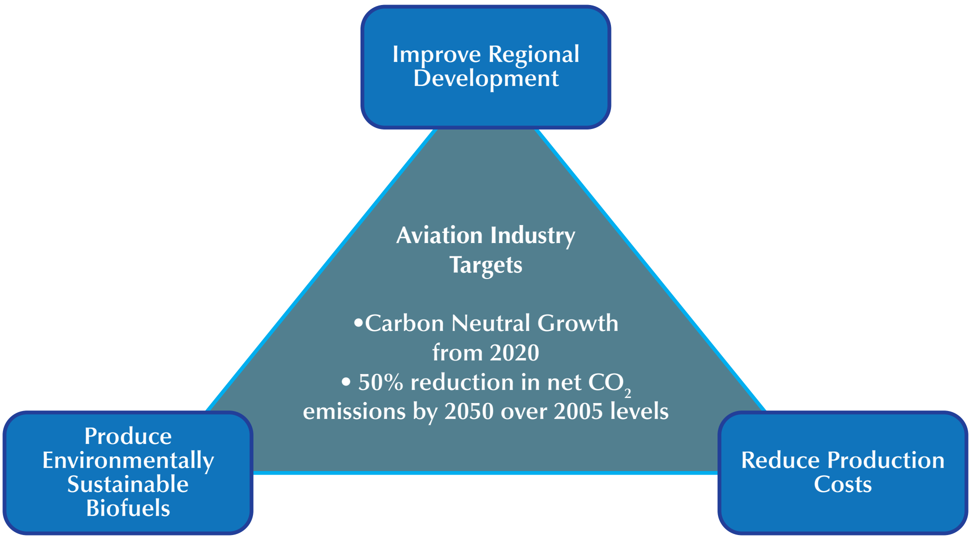

Figure 8 Strategic objectives for 2050 for the aviation industry regarding Jet fuel substitution by biofuels.

2.2. Scope

The Sustainable Aviation Biofuels for Brazil Project aimed to develop a Roadmap to identify the gaps and barriers related to the production, transportation and use of biofuels for aviation. Although there are some companies already producing and selling biofuels for aviation to be used in mixture with fossil jet fuels, aviation biofuels have not been thoroughly used, and a fully commercial industry has not yet been developed.

Considering the aviation industry vision, the main *Sustainable Aviation Biofuels for Brazil Project* objectives were:

1. to develop a Roadmap to identify the gaps and barriers related to the production, transportation and use of biofuels for aviation. Although some companies are already producing and selling biofuels for aviation to be used in mixture with fossil jet fuels, aviation biofuels have not become a standard part of the fuel supply, and a fully commercial industry has not yet been developed;
2. to create the basis for a research and commercialization agenda to overcome the identified barriers. In short, the goal is: develop a sustainable aviation biofuels supply chain, with high GHG mitigation potential;
3. to establish the foundation to launch a new and innovative industry in Brazil to produce sustainable biofuels for aviation.

BOEING and EMBRAER recognize the Brazilian experience in biofuels and the potential of this country to offer sustainable solutions in this area.

FAPESP is deeply committed to continue the research effort in this area. The present Sustainable Aviation Biofuels for Brazil Project will help to identify scientific and technology gaps in this area. In short, the broad goal of this project is to create the basis to establish a new industry (sustainable biofuels for aviation) in which the research efforts will play an important role to accomplish this endeavor.

This Technology Road Map (TRM) process is divided into many work fronts throughout the value chain, each with specific focus on corresponding large technological areas relevant to the aviation industry's envisioned future. **Figure 9** shows the **main components** of this work: Feedstock, Refining Technologies and Logistics, including Sustainability as a critical issue to be considered in the process.

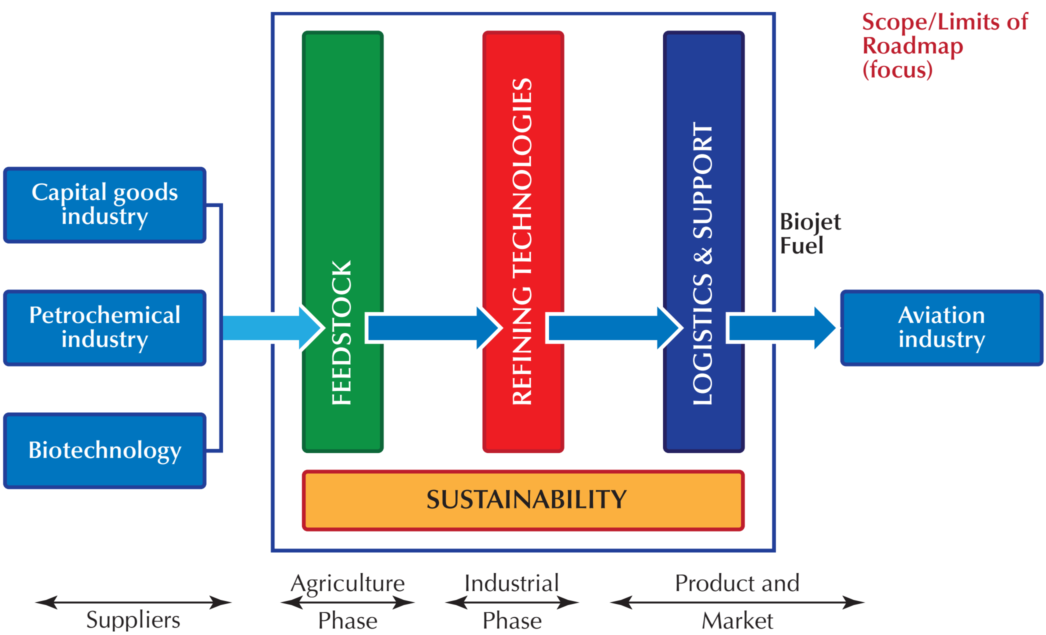

Figure 9 Roadmap Scope/Limits, Components, and main Suppliers for biofuels to the Aviation Industry.

Feedstocks are a critical element in the production of a biofuel for aviation. The feedstock to be used for this end can be rich in sugar, starch, fat, oil, fiber and obtained directly or indirectly by cultivated crops, algae, or residues.

Using this definition, a large number of feedstocks can be used in the production of biofuels for aviation. However, important requirements such as capacity to improve yields, low direct and indirect emissions, high efficiency in land use and positive social and economic impacts also need to be fulfilled. The feedstocks listed below are among the possible feedstocks that can be considered:

1. Sucrose and starch (i.e.: sugarcane, corn, sweet sorghum)
2. Oil (i.e.: soybean, jatropha, camelina, algae)
3. Fiber (i.e.: eucalyptus, cane bagasse)
4. Waste (Industrial and Municipal Solid Waste)

In the industrial phase, the component is Refining Technologies. Depending on the feedstock, there will be certain technologies used to convert it to the biofuel needed by the aviation industry. The refining technologies can be divided into two groups:

5. **Existing Technologies** (approved routes according to ASTM D7566[3]):
    1. **Fischer Tropsch Kerosene (FT using fibers)** can be produced via lignocellulosic biomass gasification followed by gas cleaning and synthesis over appropriate catalysts; it is approved for a 50% blend by ASTM. Although raw material cost (fibers) represents only approximately 0,3€/l, investment cost is about 1€/l [Workshop: "Achieving 2 million tons of biofuels use in aviation by 2020" – Brussels May/2011 – European Commission editorial team: Maniatis K., Weitz M. & Zschocke A.]
    2. **Hydroprocessed esters and fatty acids (HEFA)** or Hydrogenated Vegetable Oils is based on triglycerides and fatty acids which can originate from plant oils, algae and microbial oil and it is approved for a 50% blend by ASTM. Hydrogen demand for different feedstock qualities varies, resulting in different conversion cost for diverse raw materials like palm oil, animal fats, camelina, jatropha, etc. After removal of oxygen and saturation with hydrogen, it is necessary to catalytic crack and branch the molecules with hydrogen. Investment cost is low, but the cost of common raw materials, that can represent 70% of total cost, is presently too high to compete with conventional jet fuel. **Algal oils** can also replace vegetable oils in HEFA, but these will not be commercially available for the next years. Due to very high infrastructure cost for industrial algal cultivation it is unclear when competitiveness vs. conventional plant oil or other advanced biofuels cost will be achieved. It has the advantage of having no issues related to land use.
6. **Exploratory** (expected to be approved in coming years)
    1. **Hydrogenated Pyrolysis Oil Kerosene** is based on pyrolysis oils from lignocellulosic biomass. Pyrolysis oils can be hydrotreated either in dedicated

3 A third route was approved by ASTM in June/2014, denominated as Synthesized Iso-Paraffins (SIP). The SIP are produced from hydroprocessed fermented sugars and will be permitted for blending at up to 10% (vol) with conventional jet fuel. It refers to the route treated in this report as submitted to approval denominated DSHC (direct sugars to hydrocarbons).

facilities or co-processed with petroleum oils in refineries. Today pyrolysis oil is at the edge of research towards demonstration level. It is expected that the upgrading of pyrolysis oils will use existing refinery infrastructure, what would make it more competitive than FT.

2. **Catalytic Conversion of Alcohols to Hydrocarbon or ATJ** (Alcohol To Jet) is technically feasible but, starting with a commercial product, the final price is high. Hydrolysis of cellulosic materials from sugarcane and other cultures or residues could improve the economics, as well as other processes for conversion of wastes to alcohols.
3. **Direct Conversion of Sugars to Hydrocarbon** (DSHC) is technically feasible through genetically modified microorganisms and is reaching commercial stage, with first-of-a-kind installations getting into operation (AMYRIS, 2012; SOLAZYME, 2012), generating two main different products. The hydrocarbon obtained is an unsaturated C15 product with four double bonds, would need 4% hydrogen (weight basis) to produce jet biofuels (DSHC). The second product is microbial oil, which typically can be a very good feedstock for HEFA conversions.

For example, using sugarcane as feedstock, several refining technologies can be considered (see **Figure 10**).

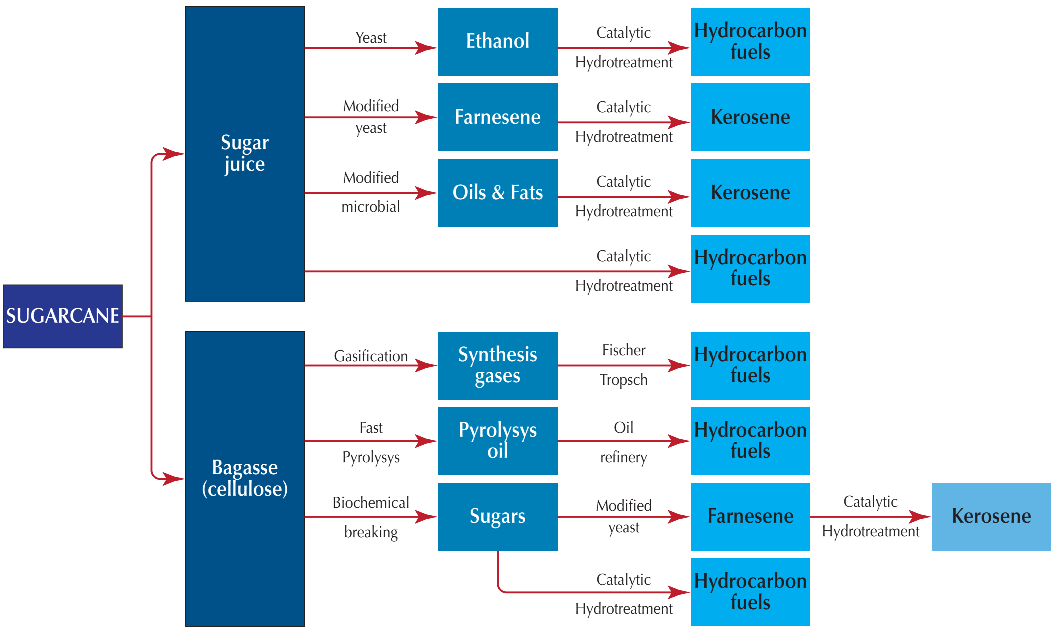

Figure 10 Different refining technology pathways to be considered for aviation biofuels using sugarcane as feedstock.

From the industrial phase and into the product and market phase there is the Logistics component. The logistics of jet fuels is a dedicated system that includes certification and strict requirements of quality assurance, quite different from those used for automotive biofuels. Jet fuels may be produced in oil refineries and distributed to the airports by oil companies through a dedicated system. A critical aspect at the jet fuel distribution chain is the quality control system (QCS) required. For instance, starting at oil refinery, with a full product quality analysis and batch certification, a product under the QCS will require specific points of control when the jet fuel arrives at a terminal for distribution and at the airport terminal, too. The jet fuel producer and distributor are required to be fully committed with the appropriate quality assurance requirements through the whole chain, up to aircraft tanks. Considering that new players can be added to jet fuel distribution chain, the logistic to be implemented will depend on where these new players will be installed and included in the chain and how they will operate

Finally, Sustainability is one of most relevant issues for the TRM process. Aspects to be considered in sustainability involve: efficiency on land use, promotion of regional rural development, low water use, no harm to air quality, maintenance or improvement of soil fertility, no competition with biodiversity and food security, and positive social development. Some specialists simply summarize the sustainability aspects to be considered in biofuels production in 3 aspects: environmental, social and economical. However, a pre-requirement and "*raison d'être*" of the Sustainable Aviation Biofuels for Brazil Project is to mitigate the GHG emissions through the substitution of fossil by renewable fuels. Therefore, low land use with high potential reduction can be considered a pre-requirement or "sine qua non" condition.

From the GHG emissions point of view, the biofuel LCA (Life Cycle Analysis) needs to be clearly evaluated considering all steps, including logistics for distribution. **Figure 11** presents a scheme on how the biofuels life cycle could be compared with the jet fuel life cycle.

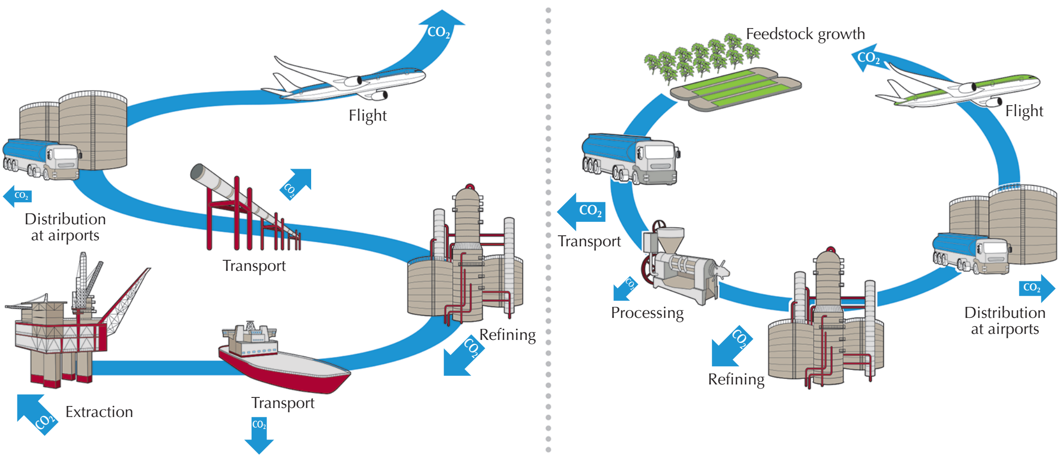

Figure 11 Comparative Life Cycle Analysis (LCA) for CO_2 emissions using kerosene (left) and biofuels (right). Source: ATAG, 2011.