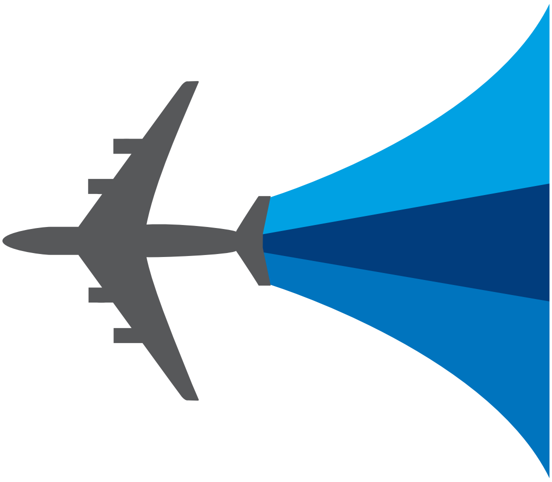

ROADMAP FOR SUSTAINABLE AVIATION BIOFUELS FOR BRAZIL

A Flightpath to Aviation Biofuels in Brazil

BOEING

EMBRAER

FAPESP

UNICAMP

Stakeholders:

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AEROSPACE INDUSTRIES ASSOCIATION OF BRAZIL

AMYRIS

ANAC
AGÊNCIA NACIONAL DE AVIAÇÃO CIVIL

ANDRITZ
Pulp & Paper

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Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

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EDITOR
Luís Augusto Barbosa Cortez

ROADMAP FOR SUSTAINABLE AVIATION BIOFUELS FOR BRAZIL

A Flightpath to Aviation Biofuels in Brazil

an initiative of
BOEING/EMBRAER/UNICAMP and FAPESP

Roadmap for sustainable aviation biofuels for Brazil:
A flightpath to aviation biofuels in Brazi

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Foreword

The aviation industry is committed to reducing its environmental impact and has established the ambitious goals to reach carbon neutral growth by 2020 and to reduce carbon dioxide emissions by 50% (from 2005 levels) by 2050. Currently, the aviation industry generates approximately 2% of man-caused carbon dioxide emissions; it is a small but growing share that is projected to reach 3% by 2030.

BOEING and EMBRAER, as leading aviation companies committed to a more sustainable future, have joined efforts to support initiatives to lower greenhouse gas (GHG) emissions derived from air transportation. These emissions represent an important global concern in the 21st century, and the growing aviation industry will need to find ways to reduce its contribution, particularly in substituting fossil fuels by sustainable biofuel.

Airlines are doing their part as well. Globally, they have created the Sustainable Aviation Fuel Users Group (SAFUG), an organization focused on accelerating the development and commercialization of sustainable aviation biofuels and representing about 30% of commercial jet fuel demand.

Brazil is internationally recognized for its long experience of using biomass for energy purposes beginning with wood, sugarcane ethanol, and biodiesel. Modern bioenergy represents around 30% of the Brazilian energy matrix, and has a long track record reconciling biofuel production, food security and rural development. Much of what Brazil has done in the bioenergy area was accomplished by long-term policies and investment in research and by building up human capacity.

In this context, BOEING, EMBRAER and FAPESP initiated this project to conduct a national assessment of the technological, economic and sustainability challenges and opportunities associated with the development and commercialization of sustainable biofuel for aviation in Brazil. UNICAMP was selected for the coordination of this study, with the charter to lead a highly qualified, multi-disciplinary research team. The project team conducted eight workshops with active participation of over 30 Stakeholders encompassing private sector, government institutions, NGOs and academia. The assessment included the most important topics from agriculture, conversion technology, logistics, sustainability, commercialization and policies. The result of this effort is this Flightpath to Aviation Biofuels in Brazil originated from the open dialogue and diverse views of the Stakeholders in a consensous manner. The report lays out the grounds to establish a new biofuels industry to replace jet fuels. In the process, we confirmed that Brazil is a place of great promise to help the world to alleviate fossil fuel dependence in aviation.

The development of a new industry will entail the participation of different sectors of the Brazilian economy including not only research institutions and biofuels producers but also feedstock producers, financial, international relations, academia, the aviation industry, and environmental and social advocacy groups. In developing sustainable aviation biofuels Brazil is seen as a key player, having a unique strategic advantage worldwide.

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the participating parties. The results, analysis, conclusions or recommendations expressed in this report are based upon consensous from a series of multi-stakeholder workshops, technical presentations, data gathering, benchmarking or otherwise specified assumptions and parameters. To the extent permitted by the law, the participating parties exclude all liability to any party for any loss, expense, damage or cost incurred directly or indirectly from using this report.

Summary

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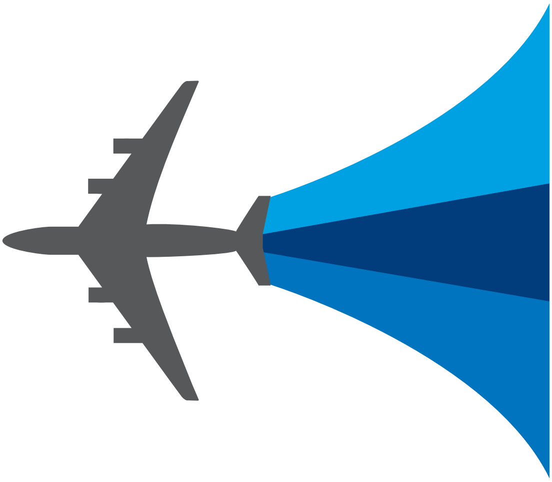
RECOMMENDED TECHNOLOGIES

RECOMMENDED POLICIES



PART I

INTRODUCTION AND CONTEXT

1 INTRODUCTION

Created and developed during the last century, the aviation industry, encompassing the airplane and aeronautic equipment industry, airlines, national defense forces, and general and business aviation companies, airports and all ancillary organizations, is nowadays an essential component of modern economy and life and has been growing at important rates, mainly in developing countries. In this expansion process, to ensure a sustainable, competitive and environmentally sound energy supply is a challenging question.

The Sustainable Aviation Biofuels for Brazil Project is an initiative of BOEING, EMBRAER and FAPESP chartered to set a R&D agenda for effective development of production routes of these biofuels, considering the use of proper feedstock, processed by innovative technologies to reach the requirements of a drop-in fuel, under strict sustainability constraints. The project has been developed during 2012 using the methodology of organizing a series of workshops to discuss every relevant issue concerning aviation biofuels and progressively designing a "roadmap" to be adopted in order to overcome the identified hurdles and effectively introduce biofuels in the regular air transportation system.

To introduce the context of the Sustainable Aviation Biofuels for Brazil Project, this session presents an overview on: aviation industry and energy, modern biofuels situation, and aviation biofuels evolution in recent years, highlighting the role of government actions in the regulatory and incentives spheres.

After these introductory subjects, the chapter goes more deeply into what was presented and discussed in the 1st Workshop of the Project, confirmed when the vision and scope of the project was confirmed by the Stakeholders, and follows on to discuss the necessary aspects to establish a Technology Road Map (TRM).

1.1 Aviation Industry and energy

The civil aviation is absolutely essential to the global economy. According to the International Air Transport Association, the air transportation industry contributes about US$ 3.8 trillion per year to the global economy, supporting the employment of 32 million people, to transport 42 million tonnes of goods and connect 2.8 billion people. One daily international long haul flight generates, in annual terms, 60 thousand passengers, 880 jobs, US$ 26 million in GDP (Gross Domestic Product), US$ 10 million in salaries and US$ 4 million in taxes (IATA, 2012).

In Brazil, air transportation is evolving rapidly, higher than the global average. Brazil is currently forecasted to become one of the largest domestic air traffic market in the world by 2014. In 2010, the Brazilian aviation sector carried over 71 million passengers and 870 thousand tonnes of air freight to, from and within Brazil. More than 62 thousand scheduled international flights depart Brazil annually, destined to 58 airports in 35 countries. Domestically, more than one million scheduled flights annually provide connections between 108 airports. In economic terms, in 2009, this activity contributed with R$ 32 billion to Brazilian GDP and employed about 684 thousand people. In addition, it is estimated that there are a further 254 thousand people employed through activities promoted by aviation, such as tourism (OXFORD ECONOMICS, 2011).

The aviation sector contributed over R$ 4.0 billion in taxes through corporation tax and income and social security contributions (both employee and employer contributions). Air passengers paid a further R$ 1.3 billion in passenger embarkation taxes, bringing the total tax contribution to R $5.3 billion. Moreover, it is estimated that a further R$ 7.2 billion of government revenue is raised via taxation through the indirect (R$ 4.4 billion) and induced (R$ 2.8 billion) channels. Not included in the figures above are domestic aviation fuel tax payments, estimated to be in the range of R$ 0.8-1.2 billion (OXFORD ECONOMICS, 2011).

The energy demand of the aviation industry is almost totally focused on petroleum based jet fuel, a form of kerosene, which has good properties to be used in jet gas turbines efficiently and safely. The global demand of jet fuel is around 250 million cubic meters per year, close to 6% of refinery output (IEA, 2011). About 2/3 of that demand occurs in OECD countries. In Brazil, the demand for jet fuel in 2011 was approximately 7 million m^3 (about 2.8% of global demand) of which the Brazilian refineries produced 75% and the rest was imported from various countries (ANP, 2012).

Figure 1 presents the projected growth of jet fuel consumption in Brazil, together with the historical evolution of production and consumption in the last 12 years. According to Sindicom, jet fuel consumption is projected to reach 12 million m^3 by the year 2020 while the number projected by EPE (EPE, 2011) is 11 million m^3 for the same year, with an annual growth around 5%. The steep increase in production, projected around 2015 due to new refineries going into operation, will have some postponement following the investment plans of Petrobras recently made public (PETROBRAS, 2012). The equilibrium between supply and demand will only occur several years later.

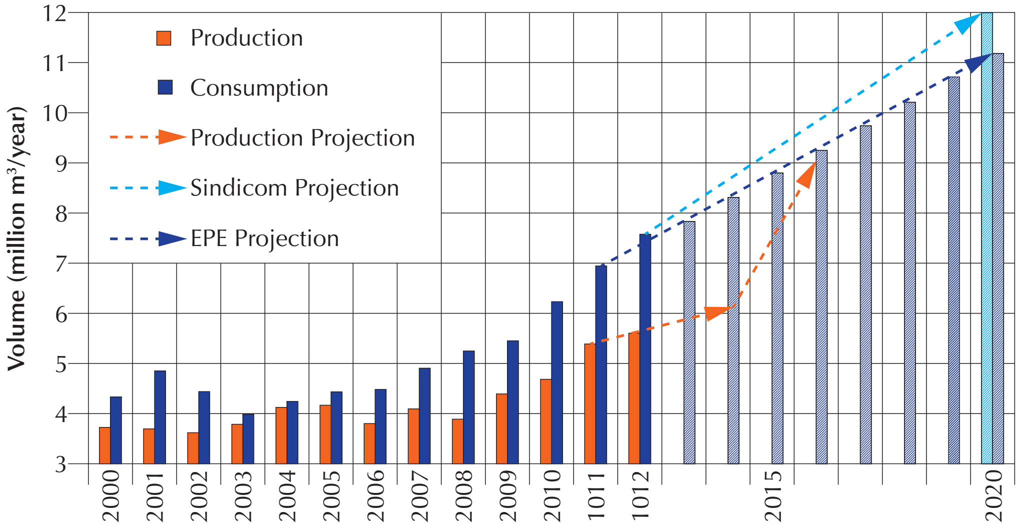


Figure 1 Jet fuel consumption and production in Brazil. Source: ANP, 2012.

Fuel represents the most relevant operational cost for an airline. As a world average fuel currently represents 34% of the operational costs (compared with 10-15% in the past decade), but in Brazil it is higher, representing around 40% of the operational cost for the airlines. Besides this high share, the volatility associated to oil price variation is another concern, introducing significant difficulties for planning and management in these companies. **Figure 2** presents the evolution of oil (referenced as Brent) and international jet fuel prices in the last years.

The pricing of jet fuel is usually done according to three models: market based formula, import parity and posted price. In market based pricing, an average spread over crude oil is US$ 9.6 per barrel. The jet fuel price at the producer gate in Brazil, about 1.0 to 1.2 US$/liter in 2011[1], is defined by Petrobras and taxed multiple times. The domestic jet fuel price is 12% higher than the regional South American and 17% higher than the global average (EBNER, 2012a).

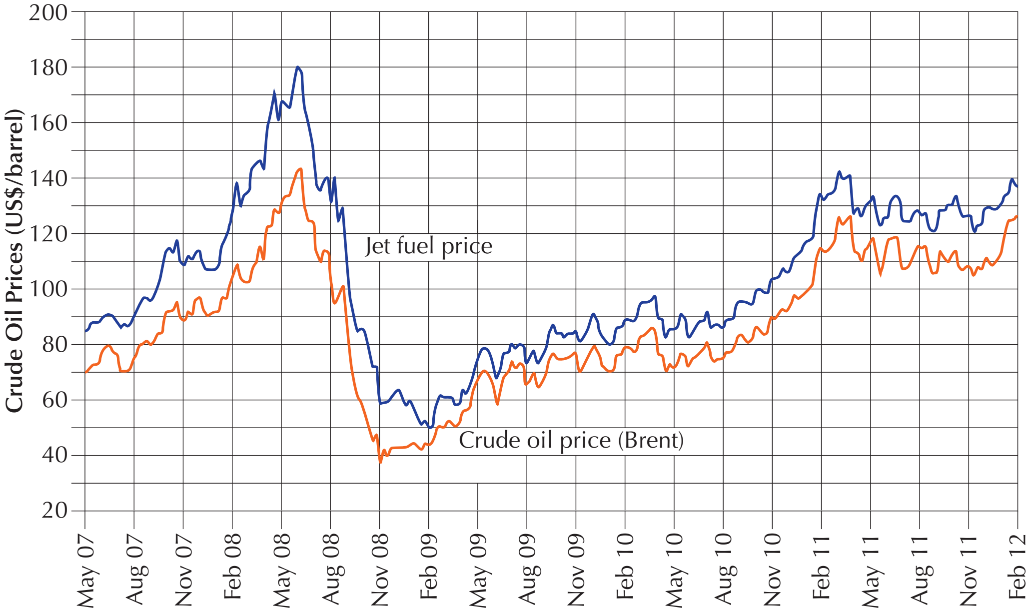


Figure 2 Crude oil and jet fuel prices in US$/barrel. Source: IATA, 2012.

1.2 Biofuels and GHG emissions

The concern about global climate change, as well as high prices and uncertainty in oil supplies have led to a growing demand for renewable energy technologies and more efficient process of energy conversion. In this context, the production and use of ethanol and biodiesel have developed dramatically in recent decades, essentially seeking to meet the demand for light and heavy vehicles used in road and urban transport. The evolution of global biofuel production is shown in **Figure 3**. Biofuels currently represent about 3% of global energy consumption to move people and goods.

The photosynthetic route of solar energy harnessing to produce liquid fuels has been deeply evaluated and, in despite of the misunderstanding remaining in some circles, there is an increasing knowledge on sound bases indicating that in several production routes (feedstock

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[1] A barrel of oil has approximately 159 liters.

production and processing) the sustainability indicators, assessing environmental, social and economic aspects, can be and in some already are very positive. As a consequence of this perception of biofuels potential and advantages, projections from institutions such as the International Energy Agency and the World Energy Council point to vectors a rising share in the future demand for this renewable energy.

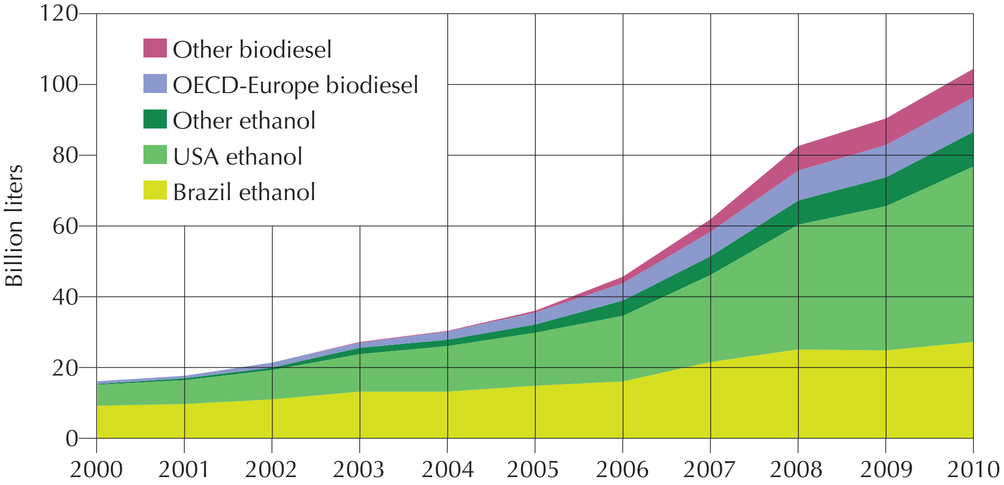
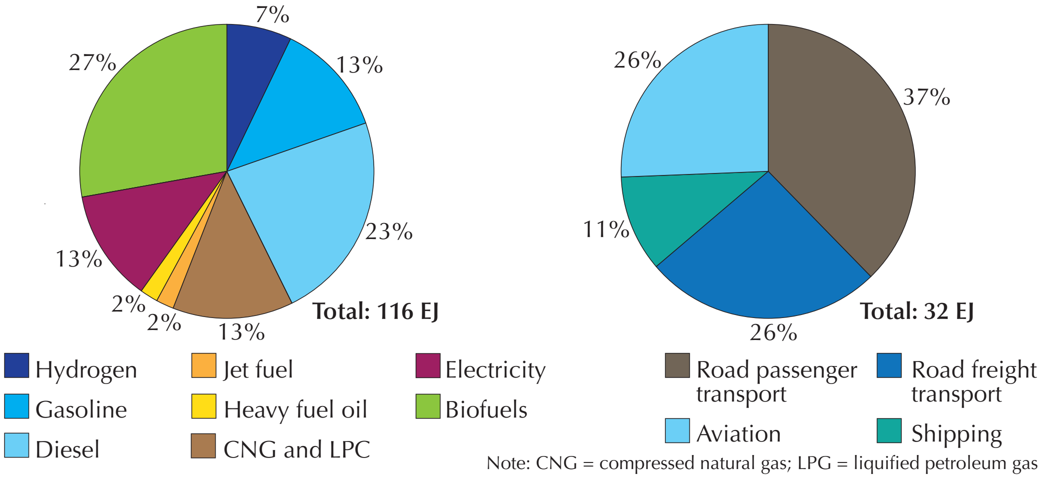


Figure 3 Biofuels global production. Source: IEA, 2010.

Figure 4 presents a synthesis from the IEA study (Blue Map scenario), estimating that in 2050 biofuel can represent about 27% of global energy demand in transport, about 116 EJ. Biofuels are expected to contribute to all modes, but road transport (63%) and aviation (26%) should take the most relevant share.



Note: CNG = compressed natural gas; LPG = liquified petroleum gas

Figure 4 Global energy use in the transport sector (left) and use of biofuels in different transport modes (right) in 2050 (BLUE Map Scenario). Source: IEA, 2010.

The Brazilian experience on liquid biofuels

In Brazil, about half of the total primary energy comes from renewable sources, mainly hydro, sugarcane and wood. The importance of the sugarcane bioenergy is high; in 2011 it accounted for 15.7% of the national energy supply (42.8 Mtoe), slightly above the contribution of hydroelectric power (EPE, 2012). In the road transport sector, biofuels were responsible for about 19% of total energy consumption in 2011.

The extensive Brazilian experience with automotive biofuel started in 1931 with the mandatory blending (5%) of ethanol from all gasoline commercialized in gas stations. In 1975, the Brazilian Ethanol Program induced a large expansion of production, by the progressive improvement of agro-industrial productivity, with the use of 25% ethanol gasoline blends and introduction of pure ethanol cars. After 1985, with the decline of oil prices, the stimulus to ethanol was reduced. Production stagnated until the introduction of flex-fuel cars in 2003. These cars represent today about 93% of sales of new cars. In 2013, straight ethanol can be used by 20 million Brazilian vehicles (mostly cars with flex-fuel engines), around 50% of the national light vehicle fleet (ANFAVEA, 2013). In the 2010/2011 harvest season, 9.2 million hectares of sugarcane fields (approx. 1% of Brazilian national area) produced 620 million tonnes of feedstock for sugar, ethanol and electricity. About 50% of the available sugar was used to produce 22.6 million cubic meters of ethanol in 2011 (UNICA, 2014). During the last decades, productivity grew at a cumulative average annual growth rate of 3.1%, in ethanol production per hectare, a noteworthy gain in productivity obtained through the steady incorporation of new technologies.

The National Program of Biodiesel Production and Use was launched in 2005, aiming to encourage small producers and farmers from least developed regions to become involved with biodiesel production and setting a progressive use of mandatory biodiesel blends in all diesel oil sold in gas stations. This blending obligation started in January 2008 with 2% biodiesel (B2) until reaching the B5 from January 2010 on. In this condition, the production of biodiesel has increased exponentially and reached 2.67 Mm^3 in 2011, based mainly on soybean (80%) and tallow (14%) (EPE, 2012).

1.3 GHG Emissions and Biofuels in Aviation

Beyond the concerns on energy costs, the awareness of the environmental impact of fossil fuel utilization, mainly related to GHG emissions, has increased significantly in the context of the aviation industry. Although the air transport currently accounts for about 2% of human-made carbon dioxide emissions, this participation is growing rapidly. If fuel consumption and CO_2 emissions were to continue growing at present rates, CO_2 emissions by worldwide aviation in 2050 would be nearly six times the current figure.

Historically, significant fuel efficiency gains have been achieved by operational improvements (such as higher load factors, utilization of larger aircraft) and by technical progress (such as more efficient engines, aerodynamics, lighter airframes). Even with this efficiency improvement, aviation CO_2 emissions are predicted to more than triple by 2050 (EC, 2011).

To address the presage of climate change and emissions from the aviation sector, some public policies responses are being developed. In this direction, the most relevant measure is the European Union Emissions Trading Scheme (EU ETS), launched in 2005 to be introduced in progressive tiers and representing relevant additional costs to the sector (OAG, 2012). Enforcement is currently suspended while negotiations for an international aviation emissions framework are underway through the International Civil Aviation Organization. According to this legislation, starting in 2012, aircraft operators (for passengers, cargo and non-commercial flights) will have to surrender an allowance per ton of CO_2 emitted on a flight to/from (and within) the European Union. This will create new costs for the entire sector of about 3.5 billion Euros per year assuming a price level of 30 Euro per allowance, introduced in progressive tiers (OAG, 2012).

Nevertheless, compared with the conventional liquid biofuels, the adoption of biofuels in aviation faces more challenging conditions, especially due to the the consumption and the high quality requirements to be met by a fuel to be used in modern aircraft engines. Thus, to reach effective technical feasibility and proper conditions to develop an international market, the aviation biofuels must have a high energy density and meet the stringent quality specifications; provide good indicators of environmental sustainability and achieve minimum levels of economic competitiveness. As an additional and relevant constraint, taking into account the global specification of jet fuel and its use distributed among many countries, it is imperative to implement aviation biofuels under the concept of “drop-in” fuel[2], as well as enhancing the operational safety as a core concept.

At present there is no sufficient clarity on feedstock and processing technologies with better potential and competitiveness (current and future), subject of analysis and discussion in the Sustainable Aviation Biofuels for Brazil Project workshops, although several pathways have been identified. Nevertheless, there are sufficient elements to indicate that the aviation biofuels, although using the background and experience achieved with the conventional biofuels (ethanol and biodiesel), represent a totally new frontier for bioenergy, imposing a new vision of the development of energy agroindustry.

As a clear sign of the interest and commitment of the aviation industry towards the development of aviation biofuels, there are an increasing number of initiatives promoting them, as presented in **Figure 5**, including demonstration flights, indicating clearly that this energy technology has been associated, from the beginning, as innovative and environmentally responsible action. Among those initiatives, it is worth noting:

1. the Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE) promoted in 2010 a study about the introduction of jet biofuels in aviation in Brazil;
2. the creation of the Brazilian Alliance for Aviation Biofuels (ABRABA, Aliança Brasileira para Biocombustíveis de Aviação) joining Brazilian companies “to discuss the various aspects of developing sustainable aeronautical biofuels driven by the growing demand to meet the requirements for reducing greenhouse gas emissions in aviation as well as to provide support for Brazil’s energy security” (ABRABA, 2012);
3. the Civil Aviation Environmental Goals definition by the International Civil Aviation Organization (ICAO), aiming to minimize the adverse effect of civil aviation on the environment and including actions to limit or reduce the impact of aviation GHG

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[2] “Drop-in biofuels” are biofuels that can be mixed with conventional jet fuel, can use the same supply infrastructure and do not require adaptation of aircraft or engines.

emissions on global climate using sustainable biofuels and efficiency gains as key elements. This agency launched the ICAO Global Framework on Aviation Alternative Fuels (GFAAF) (ICAO, 2013);

4. the creation by the US Federal Aviation Administration (FAA) of the Commercial Aviation Alternative Fuels Initiative (CAAFI), chartered to "enhance energy security and environmental sustainability for aviation through alternative jet fuels" (CAAFI, 2012), in a context where the biofuels are one prominent alternative;
5. the inclusion, in 2011, of aviation biofuels in the framework of the European Industrial Bioenergy Initiative, an important element of the EU's energy and climate change policy (EC, 2011). Also under EU sponsorship was issued the study Sustainable Way for Alternative Fuels and Energy for Aviation (SWAFEA);
6. in 2011 of the report Flight Path to Sustainable Aviation by the Commonwealth Scientific and Industrial Research Organization (CSIRO), focused a sustainable aviation fuels industry in Australia and New Zealand (CSIRO, 2011);
7. in December 2012, the European Commission postponed the full implementation of the European Trading Scheme in response to ICAO demand to treat the subject in an international forum (EU, 2012).

Many demonstration and commercial flights have been staged, involving more than 20 airlines worldwide, flying with jet fuel made out of a variety of feedstock including used cooking oil and oil crops such as rapeseed, jatropha, camelina, and palm oil (as shown in **Figure 5**, **Table 1** and **Table 2**)

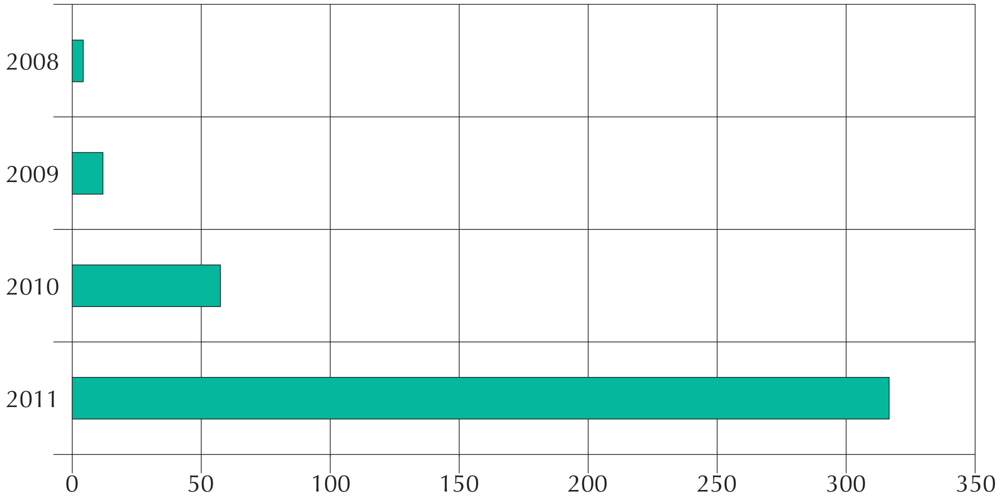

Figure 5 Number of initiatives on aviation biofuels. Source: Hupe, 2012.

During the Conference Rio+20, two Brazilian airlines made demonstration flights employing biofuels. Azul Airlines flew an EMBRAER E-195 using a drop-in renewable jet fuel produced from sugarcane by Amyris. A lifecycle analysis and sustainability study developed by the Institute for International Trade Negotiations (ICONE), indicates that this renewable jet fuel could reduce greenhouse gas emissions up to 82%, when compared to conventional fossil-derived jet fuel. In the same day, Gol Airlines made another demonstration with a BOEING 737-800 using jet fuel blended with biofuel derived from inedible corn oil and used cooking oil supplied by UOP. Before that, in 2010, TAM had already tested a jet fuel containing 50% of fuel made with jatropha seeds produced in Brazil. Recently, in October 23th 2013, Gol Airlines made the first commercial flight in Brazil using jet biofuels. The flight was realized with a Boeing 737-800 departing from São Paulo to Brasília using a bio jet fuel blend (with 25% of bio jet fuel). The biofuel used was a HEFA SPK made from a mix non-edible corn oil from corn ethanol production and used cooking oil. The company goal will be to realize 200 flights using jet biofuels blends during de Brazilian World Cup in 2014 (GOL, 2013).

This impressive set of flights assures the technical feasibility of regular use of biofuels in aviation, opening a new and challenging phase: to produce aviation biofuels competitively, respecting the environment and promoting social development.

Table 1 Recent dtbelaemonstration flights using biomass derived jet fuel (ICAO, 2011).

DATE	AIRLINE	AIRCRAFT	ENGINE	PARTNER / FUEL SUPPLIER	SOURCE OF LIQUID JET FUEL BLEND
Feb 2008	Virgin Atlantic	B747-400	GE CF6-80C2	Imperium Renewables, Boeing	20% coconut and babassu
Dec 2008	Air New Zealand	B747-400	Rolls-Royce RB211-524G	UOP, Terasol, Boeing	50% jatropha
Jan 2009	Continental Airlines	B737-800	CFM International CFM56-7B	UOP, Terasol, Sapphire Energy, Boeing	47.5% jatropha, 2.5% algae
Jan 2009	Japan Airlines	B747-300	Pratt & Whitney JT9D-7R4G2	Nikki Universal/ UOP, Sustainable Oils, Boeing	42% camelina, 7.5% jatropha, 0.5% algae
Dec 2009	KLM	B747-400	GE	GE, Honeywell, UOP	50% camelina
Nov 2010	TAM Airlines	A320	CFM International	UOP	50% jatropha
Apr 2011	Interjet	A320	CFM International	CFM, Safran, EADS, Airbus, Honeywell, ASA	27% jatropha

Table 2 Commercial flights using biomass derived jet fuel (ICAO, 2012).

DATE/ROUTE	CARRIER	AIRCRAFT	FEEDSTOCK	NOTES
23 November 2009 Amsterdan - Paris	KLM	B747	Camelina	
29 June 2011 Amsterdam - Paris	KLM	B737	Used Cooking Oil	200 city pair flights from Sept. 2011
15 July 2011 Hamburg - Frankfurt	Lufthansa	A321	Jatropoha, camelina, plants & animal fats	1,200 flights over six-month period
20 July 2011 Amsterdam - Helsinki	Finnair	A319	Jatropha	
21 July 2011 Mexico City - Tuxtila Gutierrez	Interjet	A320	Jatropha	
1 August 2011 Mexico City - Madrid	AeroMexico	B777	Jatropha	First biofuel transatlantic flight
3 October 2011 Madrid - Barcelona	Iberia	A320	Camelina	
6 October 2011 Birmingham - Arrecife	Thomson	B757	Used Cooking Oil	
13 October 2011 Toulouse - Paris	AirFrance	A321	Used Cooking Oil	Flight used 50% biofuel blend
27 September 2011 Mexico City to San Jose, Costa Rica	AeroMexico	Boeing 737-700	15% blend of camelina-derived jet biofuel	Weekly flights
7 November 2011 Houston to Chicago	United	B737-800	40% blend of biofuel made from algae	First USA biofuel commercial flight
9 November 2011 i) Seattle to Washington ii) Seattle to Portland	Alska Airlines	B737-800	20% biofuel blend made from cooking oil	First of 75 flights
22 December 2011 Bangkok to Chiang Mai	Thai	Boeing 777-200	Used Cooking Oil	
12 January 2012 Frankfurt to Washington DC	Lufthansa	Boeing 747	Biosynthetic fuel	
7 March 2012 Santiago to Conception	Lan	Airbus A320	Used vegetable oil	
13 April 2012 Sydney to Adelaide	Qantas	Airbus A330	Used Cooking Oil	Australia's first commercial biofuel flight
17 April 2012 Toronto to Ottawa	Porter	Bombardier Q400	Camelina sativa and Brassica carinata	

Institutional issues

Similarly to other innovative technologies, the development of aviation biofuels depends strongly on support mechanisms and proper public policies. As an immediate example, the adoption of ethanol and biodiesel in many countries required specific and active policies in order to reduce uncertainties and risk perception among producers and promote investments, as well as to protect consumers and the environment.

The basic reasons behind these measures are the differential advantages and externalities of using renewable energy in comparison with conventional fossil fuels. In fact, when produced and used sustainably, a biofuel is able to foster environmental benefits, jobs generation, economic activity and energy security, as main positive impacts. It is important to stress that these potential advantages of biofuels are intrinsically dependent on the production route adopted, including the feedstock productive system and the agro-industrial conversion process, which should be properly assessed by sustainability indicators.

Two basic governmental actions to support the development of sustainable biofuels are the promotion of R&D activities and the definition of a fuel specification. Regarding the first one, in the agriculture, forestry, processing and refining contexts, there are many gaps to fill, open questions to explore and processes to improve. Some feedstock proposed for aviation biofuel production, such as jatropha and algae are relatively unstudied, requiring more assessment. Venture capital can play a complementary role, and one which may be especially relevant in the case of crops such as jatropha and camelina that have a relatively small public research infrastructure but have substantial private funds for R&D. However, clearly it is a government responsibility in concert with industry to organize the scientific and technological development, stimulating basic studies, promoting demonstration projects and, as an essential matter, preparing and motivating researchers. Only with proper resources applied in a broad research agenda is it possible to screen the large number of options for aviation biofuels production systems and choose wisely the most promising ones. That R&D effort should be long-term; in order to optimize the biofuel chain.

The aviation biofuel specification must meet simultaneously to the environmental, engine and producers requirements, which are in conflict in many cases, and impose a judicious analysis before the final decision. In the case of aviation, the globalization of demand and stringent conditions of use and safety standards imposes the “drop-in” concept. A widely accepted procedure for biofuel approval process is already available (ASTM D4054, *Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives*). The ASTM standards for aviation fuels are currently under review by ANP, the regulatory agency with legal mandate for setting fuel specifications in Brazil.

After this introduction dealing with the context of the “Sustainable Aviation Biofuels Brazil Project”, the next sections present the vision and scope of the project, as consensously agreed by the Stakeholders during the 1st workshop.

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.

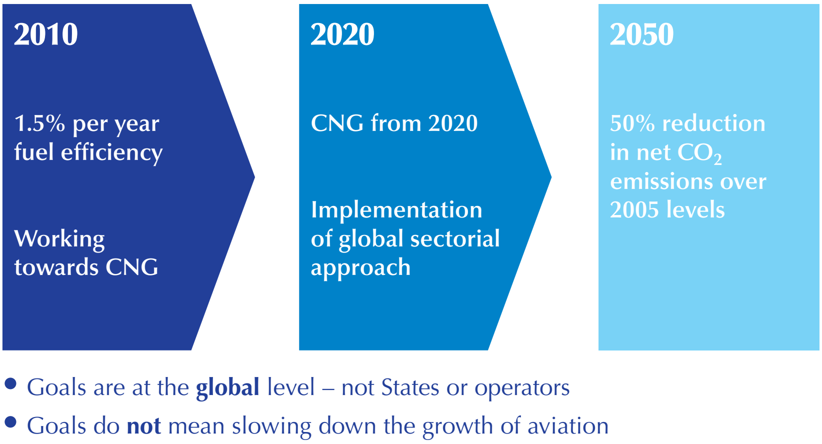

Figure 6 Expected targets for CO_2 emissions by the aviation industry for 2010, 2020 and 2050 (CNG – carbon neutral growth). Source: Freire, 2011.

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 bioenergy 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).

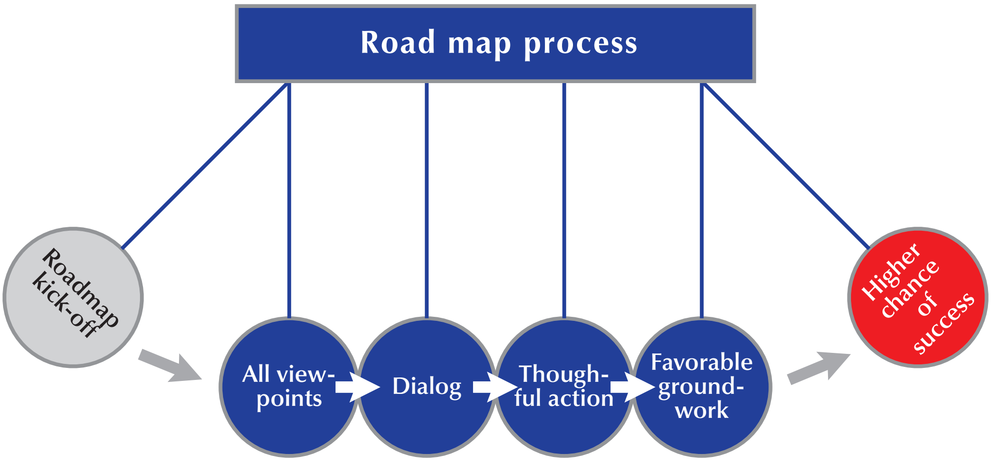

Figure 7 Steps involved in the roadmapping process. Source: Boeing apud Lyons, 2012.

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.

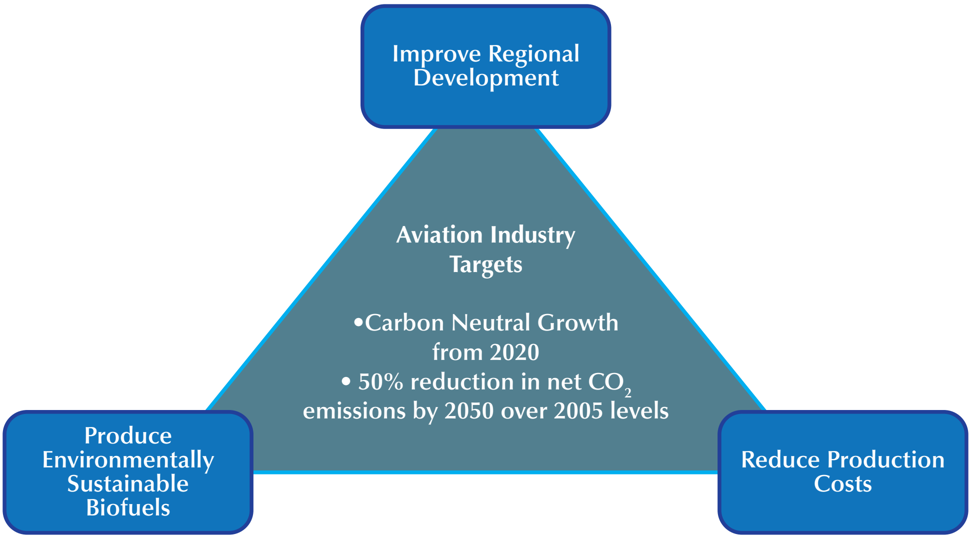

Figure 8 Strategic objectives for 2050 for the aviation industry regarding Jet fuel substitution by biofuels.

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.

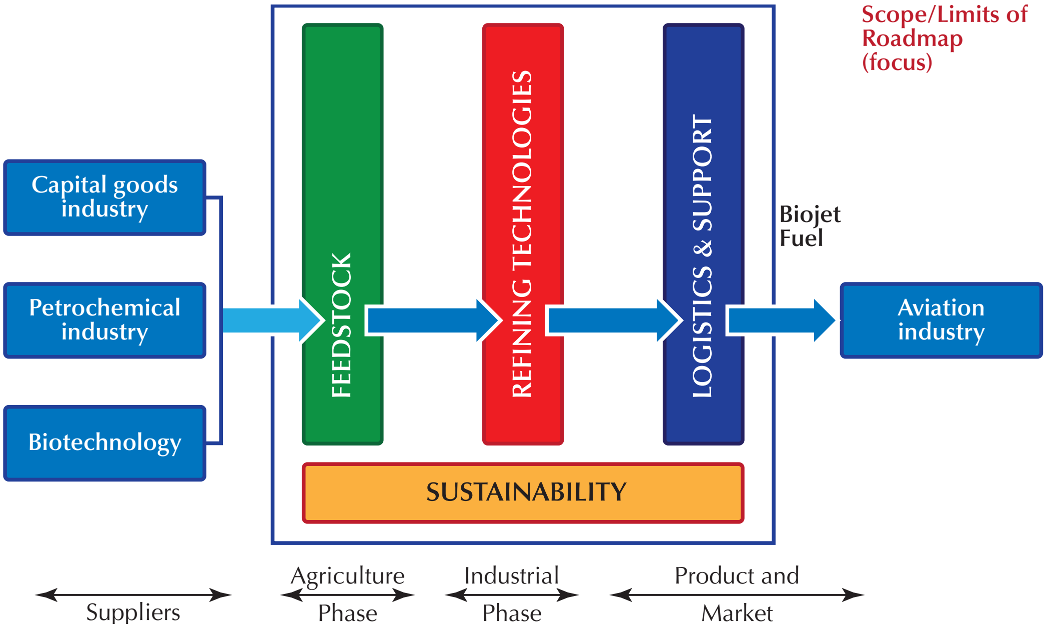

Figure 9 Roadmap Scope/Limits, Components, and main Suppliers for biofuels to the Aviation Industry.

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

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[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**).

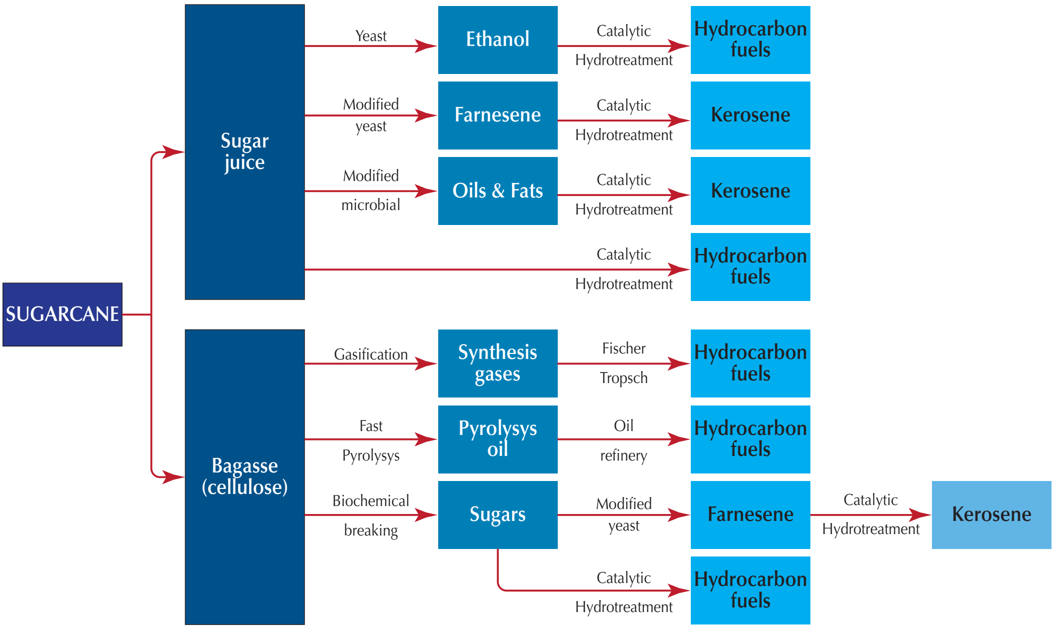

Figure 10 Different refining technology pathways to be considered for aviation biofuels using sugarcane as feedstock.

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.

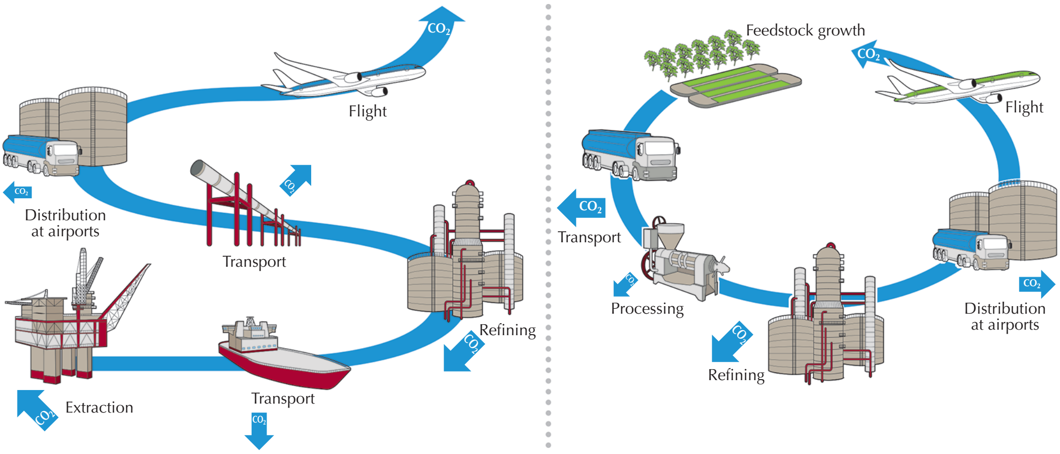

Figure 11 Comparative Life Cycle Analysis (LCA) for CO_2 emissions using kerosene (left) and biofuels (right). Source: ATAG, 2011.

3 CURRENT INDUSTRY: PRODUCTS, PROCESSES, SUPPLIERS AND CUSTOMERS

3.1 Aviation Fuel Industry in Brazil

In order to set the ground for the future energy supply of the aviation industry, this section defines where the industry is, by means of a summary of the current industry in terms of products, consumers, producers, suppliers, materials and sources of energy used.

It is recognized that airplane transportation is growing fast in Brazil in the last decade. The progress was presented in the 1st Sustainable Aviation Biofuels for Brazil Project Workshop (**Table 4**) by ANP (PINTO JR., 2012).

Table 4 Brazilian Transportation Biofuels (ANP apud PINTO JR., 2012).

FUEL (million m^3)	2011	2010	2009	2008	2007	2006	Variation %
Biodiesel	**2.67**	**2.39**	**1.61**	**1.17**	**0.40**	**0.07**	**3770.61%**
Anhydrous Ethanol	10.72	15.07	16.47	13.29	9.37	6.19	73.25%
Hydrated Ethanol	8.38	7.46	6.35	5.03	4.87	4.80	74.58%
Total Ethanol	**19.10**	**22.54**	**22.82**	**18.33**	**14.23**	**10.99**	**73.83%**
Jet Fuel	**6.96**	**6.25**	**5.43**	**5.23**	**4.89**	**4.47**	**55.74%**
Aviation Gasoline	0.07	0.07	0.06	0.06	0.05	0.05	34.67%
Gasoline C	35.45	29.84	25.41	25.17	24.33	24.01	47.67%
Gasoline A	27.07	22.33	19.06	20.14	19.46	19.21	40.94%
Diesel Fuel	51.78	49.24	44.30	44.76	41.56	39.01	32.75%
LPG	12.87	12.56	12.11	12.26	12.03	11.78	9.20%
Fuel Oil	3.67	4.90	5.00	5.17	5.53	5.13	-28.39%

Also, the growing jet fuel consumption in Brazil is following the GDP growth as presented by Nigro (2012), fact that can be used to estimate future jet fuel demand as given in **Figure 12**. Another important aspect of Brazilian market is shown in the same figure, where the jet fuel consumption grew faster in the State of São Paulo, particularly after the nineties, because most of international flights (both passengers and cargo) have used the airports of São Paulo.

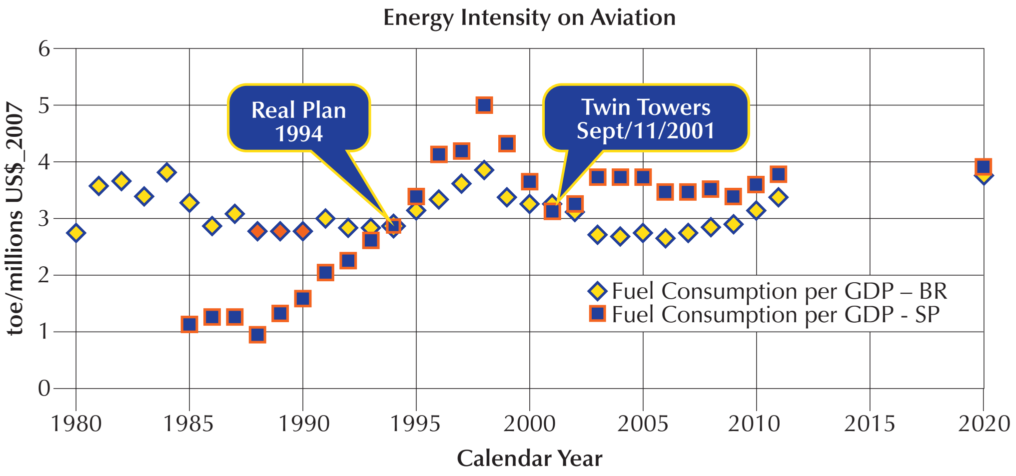

Figure 12 Energy needs for transportation segments. Source: MME/BEN, BEESP, ANP apud Nigro, 2012.

As far as Brazilian commitment with international targets regarding CO_2 reduction in the aviation industry, in March, 2011 President Dilma and President Obama made a joint declaration regarding the implementation of efforts to a partnership between the U.S. and Brazil on biofuels for aviation.

Regarding the Brazilian market, ANP (PINTO JR., 2012) presented the jet fuel consumption growth in the last decade (**Figure 13**). ANP is the regulatory agency responsible for controlling different aspects of the Brazilian fuel market, including quality control. During the presentation in the 1st workshop it was also clear that ANP will cooperate with the biofuels in aviation initiative, with the following statements made during the presentation:

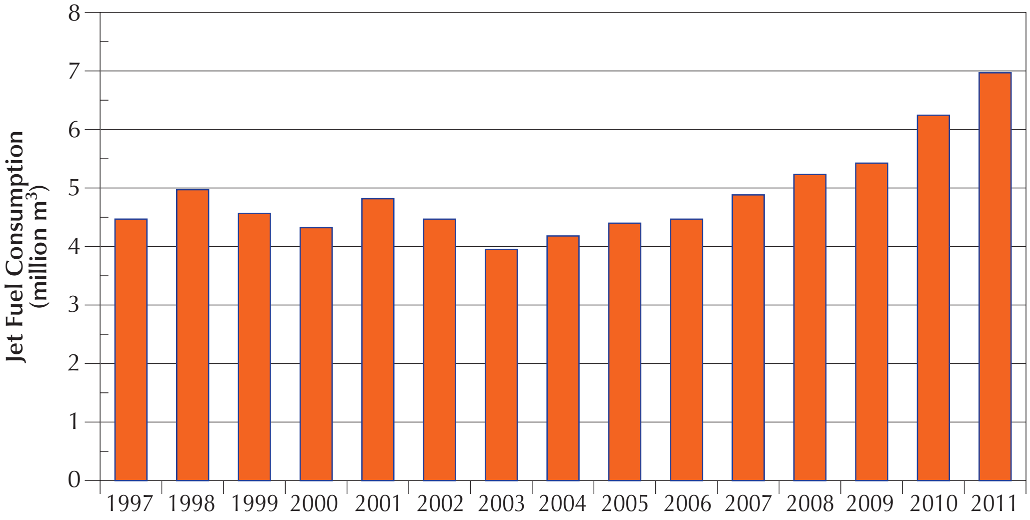

Figure 13 Jet Fuel Consumption in Brazil. Source: ANP apud Pinto Jr., 2012.

1. *ANP can contribute to the consistent planning of energy under the economic environmental and social aspects, in order to define the participation of alternative aviation fuels considering its positive externalities and the alternatives in R&D&I (new generation products begin to eclipse alternatives in the medium to longer-term);*
2. *ANP can reduce the asymmetric information: reliability for government actions and market and provide transparency data to new investors.*
3. *ANP fosters the entrance of new fuels fit for purpose in the market.*

World jet fuel demand is the fastest growing fuel globally in the last 20 years, and is projected to grow 1.8% annually. Global market for jet-A fuels in 2011 was 5.3 million barrels per day, expecting to reach in 6.4 million bpd in 2020 and 7.5 million bpd in 2030 (FAVELA, 2012).

3.2 The Bioenergy Industry in Brazil

According to Brasil (2007), bioenergy[4] in the Brazilian energy matrix is mainly composed by sugarcane products (ethyl alcohol and bagasse), wood products (firewood and charcoal) and responds for about 36.9% of primary energy production, being sugarcane products 16.9% and wood products 10.3% (Brasil, 2007).

Sugarcane products are basically ethyl alcohol 4.6% (basically used as light vehicle fuel), sugarcane bagasse 11.1% (basically used to power sugar factories and ethanol distilleries). Wood products are firewood 6.6% (used as fuel in industry, and residences), and charcoal 2.0% (basically used in industry and residences). The total amount of bioenergy used in Brazil in 2011 was 65,482,000 toe (tonnes of oil equivalent).

In 2011, biomass consumption in Brazil was used in the following sectors: energy sector 15.9%, residential 10.7%, commercial and public 0.3%, agriculture and livestock 3.7%, transportation 16.4%, industrial 53% (cement 0.6%, pig iron and steel 5.8%, iron alloys 0.9%, chemical 0.2%, food and beverages 29.3%, textiles 0.1%, paper and pulp 10.9%, ceramics 3.7%, others 1.4%).

Analyzing these figures it can be concluded that Brazilian economy, not only the transportation sector, is highly dependent of various types of bioenergy. Basically it can be stated that biomass used in Brazil for energy purposes are essentially used for ground transport, electricity production, and biomass power plant demand. In none of these sectors there exists limiting important factors, such as availability of land or competition with food, affecting biomass supply (CORTEZ, 2010).

However, the two main established sectors in Brazil regarding liquid biofuels are the sugarcane sugar-ethanol and the soybean biodiesel.

The ethanol program was initiated in 1975 after the first oil crisis that severely hit the country situation given that oil imports (80% of total consumed) represented 50% of all imports. Since then, the trajectory of the Brazilian sugarcane sugar-ethanol sector was quite

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[4] The term “bioenergy” is broader than biofuels because it includes other forms of energy from biomass, such as bioelectricity, which is the electricity generated from bio derived products.

impressive both by its contribution to alleviate oil dependence and also to improve sugar exports and promote rural development. In 2011, sugarcane ethanol responded for roughly 1/3rd of the energy consumption by vehicles powered by spark-ignited engines and sugarcane supplied 17% of all primary energy in the country.

According to UNICA (JANK, 2012) the sugarcane sector is established in 430 mills, comprising 70,000 growers, employing around 1.2 million workers, with a total revenue of US$ 48 billion and annual exports of US$ 15 billion. Brazil today is the 1st sugar producer in the world, responding by 25% of world production and 50% of world trade. As far as ethanol, Brazil is the 2nd ethanol producer in the world, responding by 20% of world production and 20% of world trade.

Sugarcane is cultivated in about 9 million ha in Brazil, only around 1% of Brazilian territory. It is currently used to produce food (sugar), fuel (ethanol), bioelectricity and plastics, but it can also serve as a base for drop-in jet fuels if science and technology advancements are made, as well as the right scenario is in place for funding, taxes, regulation and logistics, among others.

In the last decade the sector has gone through a strong consolidation process, as presented by Jank (2012). According to UNICA, the higher concentration increases competitiveness due to economies of scale and scope. Also UNICA understands that despite the recent merging & acquisitions the industry remains fragmented. **Figure 14** illustrates the sector consolidation.

Figure 14 Consolidation process experienced by the Brazilian sugarcane sugar-ethanol industry in the last decade. Source: Jank, 2012.

Another very important biofuel emerging sector in Brazil is biodiesel. The Brazilian biodiesel program (PNPB – Biodiesel Production and Use Program) was launched in 2004 mainly motivated to reduce diesel consumption which is still high comparing to other oil derivatives. The Brazilian Federal Government also wanted to combine energy goals with policies to reduce poverty in rural areas. Therefore the program favored several crops that could be cultivated by families and in regions of the Brazilian Northeast (BRASIL, 2004; NOGUEIRA; CAPAZ, 2013).

A series of measures were taken to implement the program, including a mandatory initial 2% blend of biodiesel in diesel, a "social stamp" characterizing the production by Family agriculture, and BNDES financing. As a result the biodiesel production capacity in Brazil grew fast (**Figure 15**) reaching 6.8 billion liters in 2012, according to Beltrão (2012). Worth mentioning that, up to now, Brazil does not have any established policy to increase the mandatory amount of biodiesel in diesel above 5%.

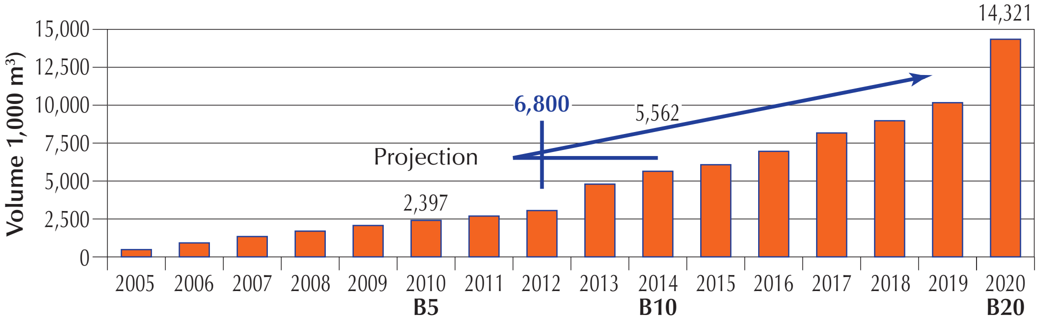


**Figure 15 Biodiesel production capacity in Brazil.
Source: UBRABIO apud Beltrão, 2012.**

Nevertheless, the dynamism presented in growing production capacity was not accompanied by the increase in biodiesel production. Reasons are the lack of competitive prices with diesel to operate on a free market and reliance on the mandatory blend, nowadays 5%, in diesel. In 2012, around 80% of biodiesel in Brazil was produced using soybean and about 15% from beef lard. The complement is obtained from other oil seeds such as cotton seeds. In the next decade it is expected to have an important growth in biodiesel production in Brazil and also the participation from other feedstocks. **Figure 16** illustrates this trend.

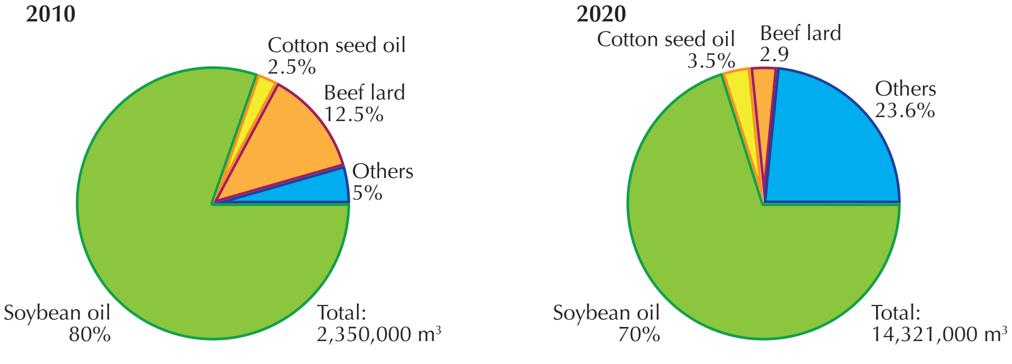


**Figure 16 Expected biodiesel production in Brazil and feedstocks.
Source: adapted from UBRABIO apud Beltrão, 2012.**

The perspective of introducing biofuels for Brazilian aviation creates opportunities for the new (upstream) bio-industry that will emerge to fulfill the requirements of the aviation industry. The existing liquid biofuels production and related infrastructure in Brazil is basically to produce sugarcane ethanol and biodiesel from different sources, mainly, soybean, lard, and other oilseeds.

The challenge imposed when biofuels for aviation are considered in Brazil involves a totally new set of measures from defining players, developing technologies, implementing logistics, rendering financial resources available, and deploying a constant and long term research effort to continuously improve biofuels for aviation continuous improvements.

Although the current state of knowledge on potential Brazilian feedstocks and technologies is considerable, it is probably insufficient considering the magnitude of problems involved in biofuels for aviation. The gaps and barriers were addressed in the workshops that took place in 2012 and are the object of this report.

3.3 Future industry: market trends and projections

This section presents market projections that may help define what the future market will probably demand. In other words, the purpose of this section is to provide an initial estimate of the market needs that must be fulfilled by the future scientific and technologic developments. A basic premise of any TRM process is that it is driven by market needs and not by the technology itself.

In Brazil, commercial aviation jet fuel demand is expected to raise both in quantity but also in its participation relatively to other fuels. Nigro (2012) has shown that in a "green scenario for 2020", where enough of biofuels would be available and applied to substitute fossil fuels in a compatible way with the Brazilian fleet on the roads in 2020, jet fuel participation would grow from its present 9% to 12% of CO_2 emissions from transport, if aviation biofuels are not used by then (**Figure 17**).

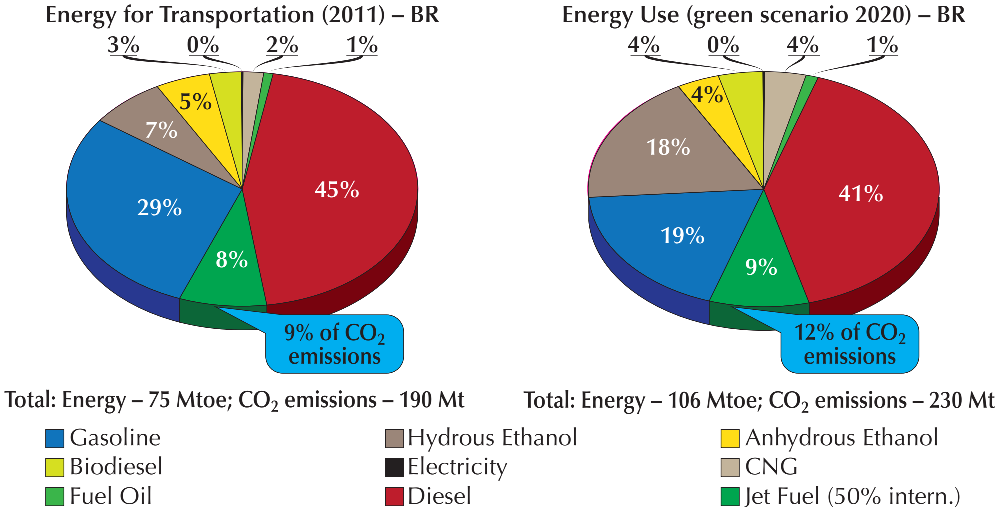


Figure 17 Biofuels for curbing CO_2 emissions from transport in Brazil. Source: Nigro, 2012.

Based on the same "green scenario for 2020" and admitting that the annual growth of jet fuel consumption, expected to be around 5%, was to be supplied by biofuels, in such a way that aviation in Brazil would experience a "Carbon Neutral Growth" without trading schemes outside the sector, the demand of biofuels for 2020 would be the ones presented in **Table 5**.

Table 5 Foreseen biofuels potential for 2020 in Brazil (Nigro, 2012).

BIOFUEL	SÃO PAULO	BRAZIL
Ethanol	19.8 billion liters	46.2 billion liters
Biodiesel	1.5 billion liters	6.2 billion liters
Biokerosene (5%)	0.2 billion liters	0.6 billion liters

According to Mcfarlane (2012) the aviation industry commitment to reduce carbon emissions is based on two-fold strategies: (a) using less fuel, by manufacturing more efficient airplanes and promoting operational improvements; (b) changing the fuel: sustainable biofuels.

Figure 18 shows the main R&D efforts to reduce CO_2 emissions and reduce noise footprint along the last decades.

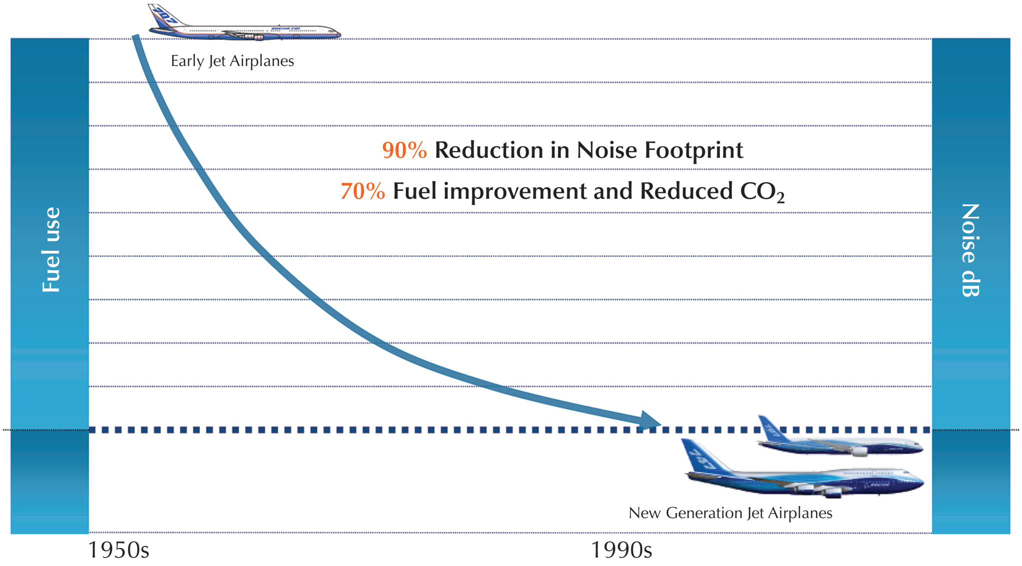


Figure18 History of environmental Progress in Commercial Aviation. Source: Boeing apud Macfarlane, 2012.

If no action is made by the aviation industry the global CO2 emissions derived from fuel burn of commercial flights will raise from about 600 million tons in 2011 to about 1200 million tons by 2050 (BOEING apud MACFARLANE, 2012).

The aviation industry is considering sustainable biomass as a priority feedstock for kerosene substitution. "Sustainable biofuels provide the only route with existing technology to put aviation on path to low carbon growth and economic and environmental sustainability" (MACFARLANE, 2012). Therefore, he concludes:

> ***"Aviation fuels should receive priority consideration for development of fuels from available sustainable feedstocks"***

Therefore, having recognized that fossil kerosene needs to be replaced by sustainable biofuels, the aviation industry has produced possible scenarios, as presented schematically below (**Figure 19**). One should observe that market based measures, like for instance the possibility of acquisition of carbon credits from other sectors by the airlines, are represented by the red triangle in the middle of this figure, on a hypothetical manner.

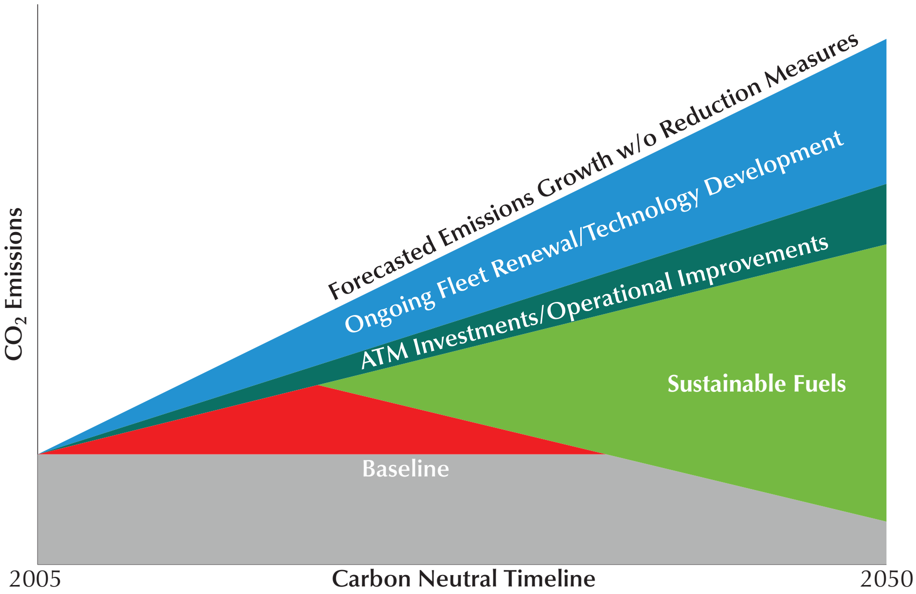
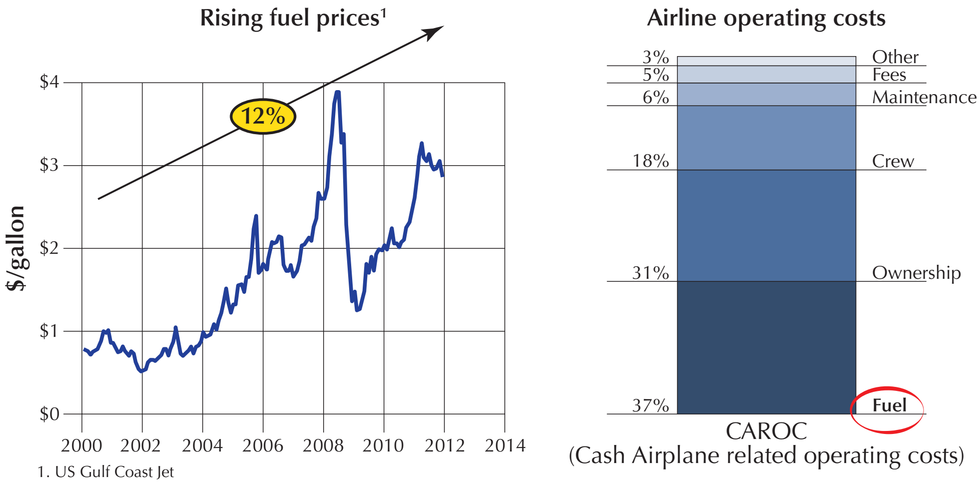


Figure 19 Aviation actions to reduce CO_2. Source: Boeing apud Lyons, 2012.

Another very important feature for the biofuels, besides the potential to mitigate GHG emissions, is related to its production costs. A special attention should be given in promoting sustainable but also **cost competitive biofuels for aviation**.

Competitive cost is considered a very important feature of jet fuels to allow the aviation industry worldwide expansion. However, the adoption of biofuels in aviation has brought a concern about that. **Figure 20** below shows how critical the impact of rising fuel prices has been in recent years and how important is the share of its costs in the overall breakdown of airline operating costs.

However, biofuels production costs from different sources are expected to decline in the coming future as the industry will learn as they will make larger volumes. **Figure 21** illustrates these possibilities from different biofuels.



1. US Gulf Coast Jet

Figure 20 Recent rising of fuel prices and airline operating costs. Source: Boeing apud Lyons, 2012.

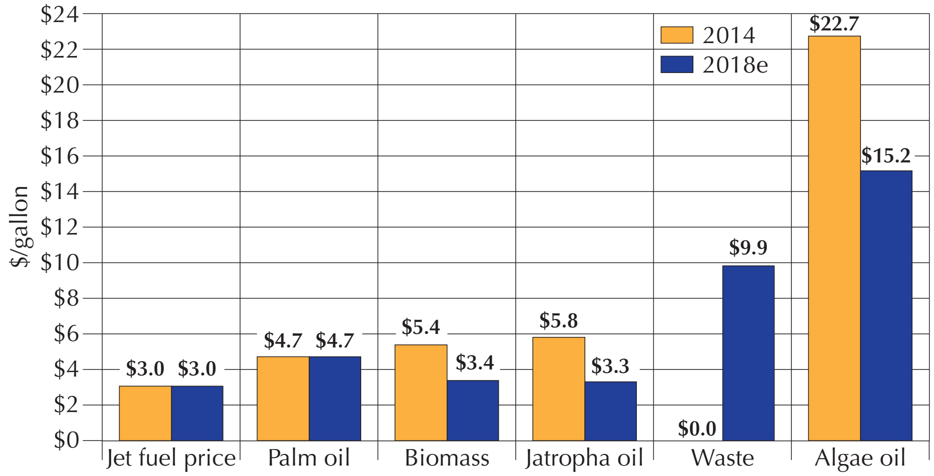


Figure 21 Cost of biofuel near (2014) and longer term (2018). Source: Boeing apud Lyons, 2012.

The demand of the aviation market for feedstocks to produce biofuels for aviation is expected to be very gradual. In order of magnitude this will be near 3 billion liters, therefore its supply should not represent any major concern, at least until 2020.

However, a more conclusive analysis is needed on how the aviation industry demand for biofuels will occur and how it will affect other sectors, even for a country such as Brazil. Growth scenarios from other sectors involving demand of land for food (including exports), for the production of biofuels for ground transportation are also needed so that there will be no shortage of feedstocks in Brazil.

Figure 22 below shows that the relative importance of sugarcane and wood products are expected to be maintained by 2030, meaning that there will be an important growth in supply of sugarcane products in the coming two decades in Brazil. However it is recommended that future demand of feedstocks for the production of aviation biofuels is well planned and with the participation of the private and public sectors, particularly the institutions related to financing productive investment.

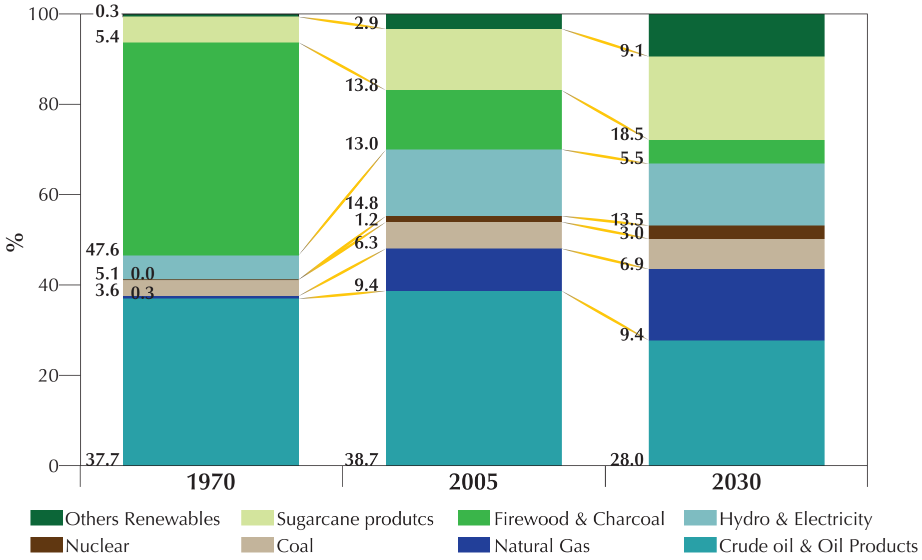
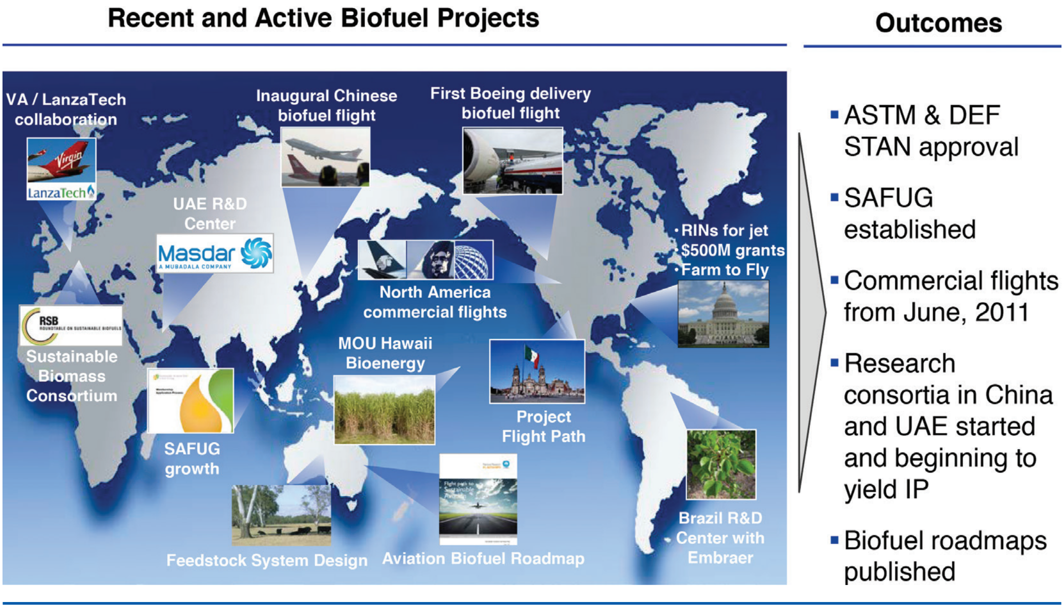


Figure 22 Expected Evolution of Energy Supply – Brazil. Source: adapted from MME-EPE, 2007.

Considering necessary technical requirements to be achieved by aviation biofuels the aviation industry supports “drop-in” fuels that: (a) Meets fuel performance requirements; (b) Requires no change to airplanes or engines; (c) Requires no change to infrastructure; (d) Can be mixed or alternated with today´s Jet-A fuel (LYONS, 2012).

As far as the aviation industry goals, Boeing has set a goal that there will be enough global supply of sustainable aviation biofuel to address 1% aviation fuel by 2015 (~600 M gallons) in 3-5 large refineries, using 1.5 Mha of agriculture land with sustainable energy crops and near price parity with traditional jet-A. Regarding necessary actions, BOEING is developing core activities such as trying to create support and advocacy, helping to promote feedstock and pathway R&D, and obtaining fuels approval (LYONS, 2012).

Figure 23 below shows several BOEING collaborations can be mentioned worldwide to promote use of biofuels for aviation.


Recent and Active Biofuel Projects

Outcomes

- ASTM & DEF STAN approval
- SAFUG established
- Commercial flights from June, 2011
- Research consortia in China and UAE started and beginning to yield IP
- Biofuel roadmaps published

Figure 23 Boeing global biofuel engagements. Source: Boeing apud Lyons, 2012.

3.4 Relevant limiters

This section presents some of the most relevant limiters for the development of the aviation biofuel industry in the future. The points presented here were derived from the breakout session that took place in the 1st Workshop of the Sustainable Aviation Biofuels for Brazil Project, focusing on the previously established vision. The result is summarized below:

1. **Technological limitations**
    1. lack of technological alternatives (industrial processes and feedstocks);
    2. lack of investment in R&D for feedstocks and processes;
    3. availability of fuel efficient airplanes from 2015 and beyond;
    4. productivity of feedstocks (example: sugarcane);
2. **Infrastructure limitations**
    1. airport infrastructure and poor traffic management;
    2. transport, distribution and storage: general logistics gaps for fuels in Brazil;
3. **Sustainability related limitations**
    1. availability/expansion of production of feedstock and sustainability (social and environmental) issues related to agricultural feedstocks;
    2. certification: accelerates acceptance of biofuels for aviation, but may help or be a barrier to its development, depending on strictness of standards;
    3. competition with other uses of feedstock;
    4. civil society perception/public opinion;
4. **Policy limitations**
    1. lack of public policies to motivate investments on biofuels for aviation (development and adoption);

    2. approval process of biofuels for aviation (similar to ASTM);
    3. taxes;
    4. low/stable price of gasoline in Brazil;

5. **Cost related limitations**
    1. costs of final product/competitiveness of fuel;
    2. cost of processing/technologies;
    3. feedstock costs (85% of the cost, in some cases);
    4. price volatility and supply risks (feedstocks);
    5. lack of financing alternatives.

Final considerations on TRM process

The authors of this report sought to present the context in which the technology roadmapping (TRM) was conducted. A long term vision for the aviation industry in Brazil has been presented, as well as the scope of this research project and its strategic goals. The report also described the current state of the industry, in terms of products, customers, producers, suppliers and processes, indicating probable market trends that will demand adaptations in those and also some relevant limiters to fulfill the long term vision.

This part of the roadmap report has a general purpose, which means that it sets the ground for the TRM process as a whole. It defines a vision, scope, and current state of the industry and future needs. The next chapters of this report will deal with each of the TRM components – Feedstock, Refining Technologies, Sustainability, R&D, Commercialization and Policies issues.

A series of 8 workshops was organized by the Sustainable Aviation Biofuels for Brazil Project in 2012 to identify the technological capabilities and needs of each TRM issue. Each workshop has addressed the following:

1. identify the "product" that the component will focus (i.e.: products and processes);
2. identify critical system requirements, its targets and how they should evolve in the time frame (horizon);
3. specify the large relevant technology areas that contribute to meet the critical system requirements, including current scientific and technological capabilities;
4. specify the technology drivers of each technology area and its targets in the time frame (horizon);
5. identify alternative technologies and their time frame (horizon);
6. recommend the technology alternatives to be followed;
7. identify R&D gaps and other important limiting factors.
8. briefing to stakeholders

The project team of the Sustainable Aviation Biofuels for Brazil Project has identified possible pathways which have been used to point the technology barriers and gaps.

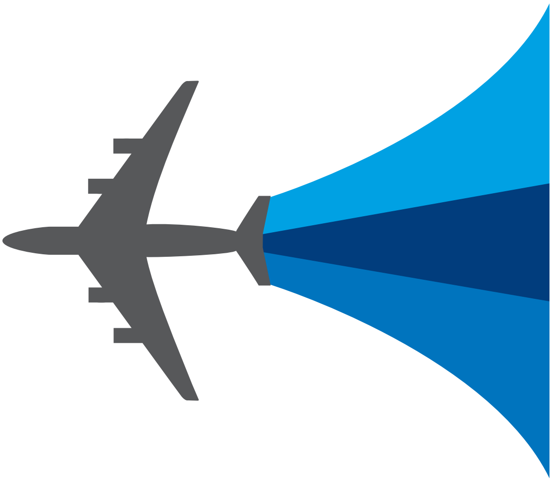
The R&D and Commercialization Workshop summarized all R&D and limiting factors identified in the workshops, adding business aspects to the discussion. This assessment naturally depends on the focus or perspective from which the biofuel is being evaluated. For example, if the evaluation is being conducted for cost analysis, each step of production and distribution needs to be quantified. It is well known that, in general, the feedstock cost plays an important role in biofuels production. In case of sugarcane ethanol it can be close to 70% and in case of biodiesel up to 80 or 90%. Another perspective, actually the main objective of the Sustainable Aviation Biofuels for Brazil Project, is to analyze the proposed biofuel (feedstock and refining technology) from the CO_2 emissions perspective. In this case the entire LCA will need to be performed to analyze its GHG mitigation potential and where the main questions to be answered remain.

The Policy and Incentives Workshop proposed a set of policies to help develop an aviation biofuel industry based on sustainable biofuels. One of the essential parts of the present roadmap is the discussion, identification of gaps and challenges to be overcome. These gaps and challenges can be of S&T nature and also related to infra-structure, improve of human resources qualification, for example. From the workshops and discussions a set of policies have been defined to provide conditions so that biofuels for aviation can be produced, transported and distributed in a sustainable way, meaning also low cost for the final consumers.

The workshops have provided valuable information to develop scenarios/pathways, which were analyzed based on assessment of likely commercial feasibility in 2015-22 timeframe, and considering long term timeframe (2050). Each workshop gathered stakeholder perspectives and insights on prospective pathways. The specific workshops were:

Workshop	Venue	Date
1 - Project Overview	FAPESP, São Paulo, SP	April 25-26, 2012
2 - Feedstocks	ESALQ/USP, Piracicaba, SP	May 22-23, 2012
3 - Refining Technologies	FEQ/UNICAMP, Campinas, SP	July 11-12, 2012
4 - Sustainability	FIEMG, Belo Horizonte, MG	August 22-23, 2012
5 - Policy and Incentives	Embrapa Agroenergia, Brasília, DF	September 11-13, 2012
6 - Logistics & Support	ANP, Rio de Janeiro, RJ	October 17, 2012
7 - R&D and Commercialization Gaps	CTA, São José dos Campos, SP	November 28-29, 2012
8 - Briefing to Stakeholders	FAPESP, São Paulo, SP	December 12, 2012

A term of reference (ToR) was prepared by specialists from the Project research team in each of these topics covering technical and logistics difficulties and barriers, LCA, and where more research is needed.



PART II

NEEDS AND TECHNOLOGICAL CAPABILITIES

4 DESIRED PRODUCTS, TECHNOLOGIES OR PROCESSES

There are many routes to produce jet biofuel because of the several options of feedstock and transformation technologies in store or being developed. The main challenge for jet biofuel is to obtain cost reduction, environmentally sustainable production and improvement of rural development taking into account the combination of the most adequate feedstock and refining technologies rather than for feedstock or processing individually. Logistics also plays an important role because plant production has limitations due to climate, soil type, etc, and not all crops can be produced everywhere. In addition, plant material is usually bulky. Therefore, where the feedstock is produced, and all the costs associated with transportation of raw and intermediate materials, and of the jet fuel itself may determine the economical viability of the whole process.

4.1 Feedstock

4.1.1 Biomass production

High agricultural prices combined with strong policies for the adoption of biofuels have transformed the availability of feedstocks for biofuels in a global challenge, especially because the opportunity costs of agricultural-based feedstocks have been increasing. On the other hand, the portfolio feedstock options is vast: oil-bearing crops, sugar/starch crops, cane bagasse, algae, agricultural residues, forestry residues, cooking oil, municipal solid waste, flue gas and tallow. Due to the increasing interest in producing biofuels, these options are being studied by different organizations, with different refining processes and in several regions.

Some of the options, such as sugarcane, soybean, palm, sunflower and tallow, are already being used for producing bioethanol or biodiesel in Brazil. The exception in this group in Brazil is probably cassava.

Other feedstocks, such as camelina and jatropha, are in the early stages of introduction as agricultural crops in Brazil and still require agronomic research. Residues from agricultural production and forestry, and co-products such as sugarcane bagasse, are available but their use depend more on the development of new or cost-effective refining technologies. Flue gas, municipal solid waste, cooking oil and sewage are alternatives being developed only in other countries, but some of these have great potential in Brazil, considering the high population and large cities that abound in this country.

Because Brazil has very favorable conditions for agricultural production (land and water availability, rain feed agriculture, millions of hectare of pasture land available, good climate in most regions, and long tradition in agriculture), the production of biofuels from residues is less developed than in other countries in which the agricultural sectors have more constraints to expand. On the other hand, exactly because the Brazilian agriculture sector still has room to expand, issues such as food versus fuel and indirect land use change has less importance than in other countries, although they must be taken into account in the sustainability debate. Issues such as the compliance with labor and environmental regulations are strongly raised by NGOs and the civil society. However, the feedstock options examined in this report also include plant residues, wastes, by-products and non-food crops that can eventually be grown in marginal lands, which minimizes competition with food production. Despite the particular situation of Brazil regarding that issue, the food x fuel and indirect land use change debate is strong in some international arenas. The European Unit has a proposal for revision of the Renewable Energy Directive (RED) which, among other things, places a 5% cap on the amount of food crop-derived biofuels used to meet the EU's goal of reducing transport energy usage by 10% by 2020 (EC, 2011).

This section of the report summarizes the discussions on feedstocks for biofuels from the 2nd Sustainable Aviation Biofuels for Brazil Project Workshop. The workshop was organized in two parts; in the first, invited specialists made presentations focused on broad range of feedstocks and in the second part a group discussion covered the strategic potential, the technical risks, and the commercial risks associated to the feedstocks. The following feedstocks were addressed through individual presentations or in the group discussions: sugarcane, sweet sorghum, cassava, elephant grass, soybean, palm, jatropha, camelina, photosynthetic algae, sunflower, rapeseed, peanut, other Brazilian palm trees, other oils, forestry wood residues, cane bagasse, industrial forestry residues (pulp, sawdust, bark), agricultural residues (straw, grasses, etc.), flue gas, municipal solid waste (MSW), used cooking oil (UCO), tallow and sewage.

With respect to the current situation of the feedstocks in Brazil, four topics are relevant: basic indicators (yields and availability), costs and prices, GHG emissions and savings and economic competitiveness against jet biofuel prices.

Brazil has a unique combination of significant availability of land already cleared for agriculture, a dynamic agriculture sector presenting strong productivity growth, a large amount of legally-protected native vegetation, strong conservation laws, and human health and safety regulations for rural activities equivalent to urban activities. This remarkable combination places Brazil, from a feedstock supply perspective, in a good position, if policies are carried out, to develop an aviation biofuel program in compliance with responsibility principles and sustainability requirements.

The agricultural sector occupies 30.4% (23.3% pasture land and 7.1% agriculture and planted forests) of the Brazilian territory, while 65% of the territory is covered with native vegetation (**Figure 24**). Legally-protected native vegetation (conservation units and indigenous reserves) represents 40% of the total remaining vegetation. Although this is a significant amount of land protected, it is highly concentrated in the Amazon Biome. The other 60% are located in private properties, from which 50% of total remaining vegetation is protected by the National Forest Code, considering the definition of the legislation approved in 2012. Annual and perennial crops, however, have a small share of the total agricultural land: only 23% (7.1% of the total Brazilian territory). The majority of the agricultural land is occupied with pastures, used mainly for beef cattle production.

Brazil has very good conditions to supply high amounts of feedstocks for biofuels. In addition of having plenty of area for agriculture expansion, the output of Brazilian agriculture is increasing steadily at a rate much higher than that of the cropped area (**Figure 25**). For instance, grain yields increased by 169% from 1992 to 2012 whereas the cultivated area expanded only by 49%. This was done with the incorporation of modern agriculture technologies such as the use of fertilizers to overcome problems of the low soil fertility of most soils: fertilizer consumption increased from 9.28 million tonnes to 29.54 million tonnes (+218%) (MAPA, 2012; CONAB, 2012, 2013).

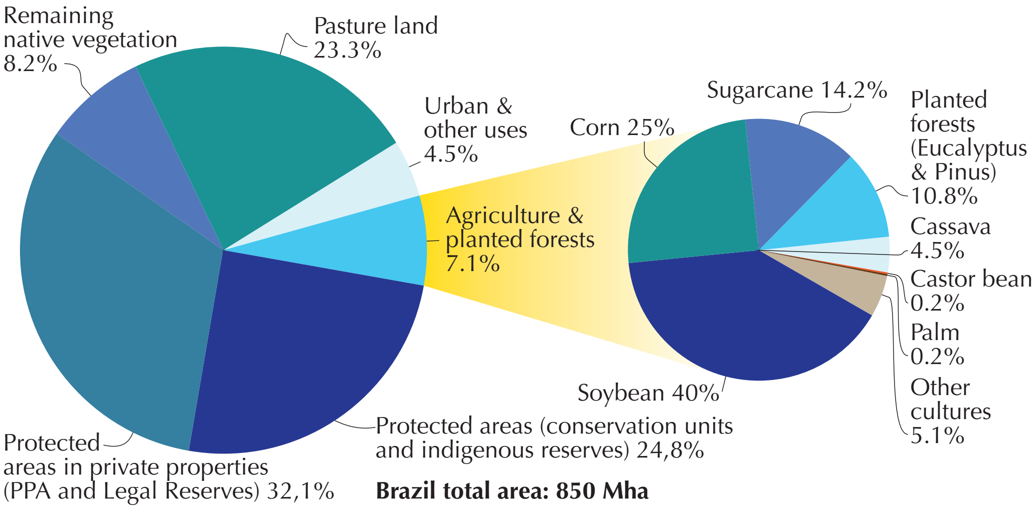


Figure 24 Land Use and planted area with some biofuel feedstock in Brazil and potential for expansion.

Notes:

1) The data on Conservation Units exclude the areas called Environmental Protection Areas (APAs); 2) The Permanent Protection Areas (PPA) include buffer strips along rivers, high slopes areas, and top of hills; 3) The data for other natural vegetation areas include Quilombola's areas, public forests and other remaining natural vegetation areas; 4) The protected areas in private properties were estimated based on the new Forest Code, approved in 2012.

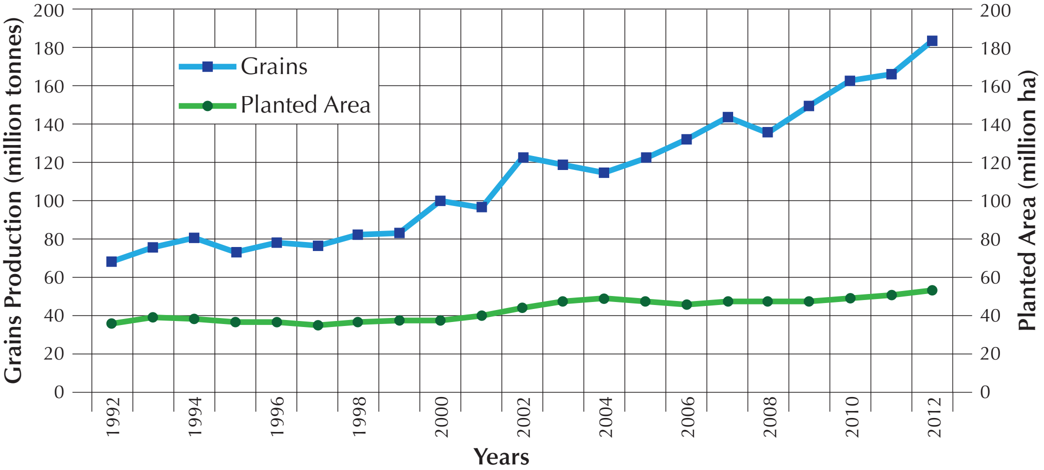


Figure 25 Evolution of grain production and planted area in Brazil in the past 20 years. Source: CONAB, 2013.

Table 6 summarizes the basic indicators for different feedstocks, and comparing feedstocks. The first criterion is the availability of the feedstock in Brazil (production and planted area). Crops such as sweet sorghum, camelina, jatropha and elephant grass have negligible planted area in Brazil. Peanut, castor bean, sunflower seed and even palm are still small in Brazil. In terms of energy yield per hectare, the second criterion, the situation of each feedstock is more associated to natural potential than specific conditions of producing in Brazil. Energy yield was calculated for the main feedstock of the crop (for example, soy oil) and total energy yield, including co and by-products (soy oil and meal).

The third criterion is economics. Producer price and production cost give an idea of the cost of energy content of the feedstocks. Given that the focus is on the feedstocks and not on the final biofuel product, prices and costs for the biofuels are not included in the table. Energy balance and GHG emissions and savings are items associated to the sustainability of the biofuels produced from the feedstocks. Differently from the other items, they are not necessarily specific to the production conditions in Brazil and they are the only item focusing the final biofuel product and not the feedstock. Several of them were collected in literature review. As any life cycle analysis, they were based on several assumptions that might not be the same for all biofuel types.

In order to understand the table, it is also necessary to read the sources and assumptions used to prepare.

The highest energy yields per area are obtained with C-4 grasses such as sugarcane and elephant grass, and trees such as eucalyptus and pinus. Paulownia was also taken into account along the roadmap studies but there is little data available. Although trees of the Paulownia genus (*Paulownia* spp) have interesting characteristics such as fast growth and are adapted to several environments, they are not extensively cultivated in Brazil and their actual potential as jet fuel feedstock remains to be proven. However, eucalyptus is a well established crop in Brazil, where it is grown successfully in many regions. Currently Brazil has 6.5 Mha of planted eucalyptus and pinus - 75% eucalyptus and 25% pinus (ABRAF, 2012), an area almost equivalent to that of sugarcane. Other planted trees, including Acacias (*A. mearnsiie*), rubber tree (*Hevea brasiliensis*), parica (*Schizolobium amazonicum*), Teca (*Tectona grandis*), Araucária (*A. angustifolia*), Populus (*P. spp*), are grown in Brazil in smaller scale, but, still a large area, totaling 0.49 Mha (ABRAF, 2012) and may be suitable options.

Another comparative advantage of planted trees in Brazil is the high yields obtained (**Figure 26**). Research efforts have allowed a favorable yield evolution: from 2005 to 2011 eucalyptus yields increased from 36.7 to 40.1 m^3/ha.year. Average yields of pinus and teca were 35.9 and 14.7 m^3/ha.year in 2011 (ABRAF, 2012). Yields in top farms can be much higher. With an average harvesting cycle of 7 years, 1 ha of eucalyptus can yield around 280 m^3 of round wood. Around 20 m^3 of forest residues are also produced (see Logistics), which must also be considered as potential feedstock for bioenergy production because wood may have other better paid options.

The potential for sustainable wood annual production in Brazil in 2011 was 255 Mm^3 (196 Mm^3 of eucalyptus and 59 Mm^3 of pinus). About 36% of the wood produced went to cellulose and paper production, 26% was for lumber & processed wood. Vegetable coal for the steel industry consumed about 10% and firewood and other used another 26% (ABRAF, 2012). Therefore, part of the wood is already used for energy production. There is plenty of room for planted forest expansion in Brazil and the planted area is growing relatively fast: in 2005 5.29 Mha were planted with eucalyptus and pines; in 2011 the area was 6.52 Mha, an increase of almost 23% in 6 years (ABRAF, 2012).

Table 6 Basic Indicators of Agricultural-Based Feedstocks.

Feedstock	Planted Area	Production	Yield			Producter Price	Production cost		Energy/ balance	GHG	
			Physical	Energy content GJ/ha/year						Emission	Saving
	1,000 ha	1,000 tons	tons/ha//year	Main Feedstock	Feedstock + co-product	R$/ton	R$/ha	R$/ton	MJ/MJexp	gCO_2eq/MJ	% reduction
Sugarcane	8,521	595,127	84	145.2	448.3	65	4,811	60	8.3	24	71%
Soybeans	24,088	74,942	3.1	22.2	60.0	1,ev017	1,567	475	4.5	50-58	40%-31%
Corn	15,018	71,490	4.8	92.7	119.2	367	1,446	289	NA	37-43	56%-49%
Cassava	2,673	24,314	38	169.6	262.9	185	4,281	122	2.7	45	46%
Sorghum (sweet)	NA	NA	30	31.8	31.8	NA	NA	NA	NA	NA	NA
Peanut	99	314	4.2	70.9	89.6	1,286	3,676	865	NA	NA	NA
Castor bean	119	26	1.5	31.5	31.5	1,320	1,574	1,049	NA	NA	NA
Sunflower seed	78	122	2.2	39.6	62.7	917	1,049	477	NA	35-41	58%-51%
Camelina	NA	NA	1.5	22.5	56.3	NA	NA	NA	4.0	25	70%
Palm	109	1,301	22	180.0	243.3	250	4,229	218	8.7	32-37	62%-56%
Jatropha	NA	NA	4.5	57.4	107.9	601	1,889	420	5.5	18-38	79%-55%
Elephant grass	NA	NA	25	–	297.7	NA	NA	NA	7.7	15	82%
Eucalyptus (m^3)	4,874	117,628	40	–	321.1	52	1,149	28	NA	17-22	80%-74%
Pinus (m^3)	1,642	49,,811	37	–	287.4	NA	NA	NA	NA	NA	NA

Notes:

- Heating Value (MJ/liter, MJ/kg). Ethanol: 21.2, 26.9; Biodiesel: 33.0, 37.5.
- Heating Value (MJ/kg): Soy meal: 15.4; Corn DDGS: 18.4; Cane bagasse (wet): 8.9; Jatropha cake: 17; Eucalyptus (wood): 12.98; Eucalyptus (bark): 8.78; Elephant grass (dry matter): 15.9; Cane trash (wet, dry): 13.5, 19.2;
- Data for Eucalyptus: density: 0.6 kg/m^3; wood/celulosis: 4 m^3/ton; bark: 7 ton/ha; rotation: 7 years.
- Data for Pinus: rotation: 15 years
- Content data (kg/ ton of bean). Soybean: Oil (190), Meal/Cake (790); Peanut: Oil (450), Meal/Cake (290); Castor bean: Oil (550); Sunflower: Oil (480), Meal/Cake (280); Camelina: Oil (400), Meal/Cake (600); Jatropha: Oil (340), Meal/Cake (660).
- Data for Palm (kg/ton FFB): Oil (220), Palmist oil (25), Cake (220).
- Productions. Sugarcane: Ethanol (81.5 liters/ton), Bagasse (280 kg/ton), Straw/trash (140 kg dry matter/ton and 164.7 kg/ton); Sorghum (sweet): Ethanol (50 liters/ton); Corn: Ethanol (2.77 gallons/bushel), DDGS (17 pounds/bushel); Cassava: Ethanol (210.5 liters/ton of root), Plant (25 ton/ha and 176 liters/ton).
- GHG, Saving (% reduction): fossil fuel comparator 83.8 gCO_2eq/MJ;
- NA: not available.

Sources and assumptions:

FEEDSTOCK	PLANTED AREA	PRODUCTION	YIELD		
			PHYSICAL	ENERGY CONTENT	
	unit.	unit.	unit.	Main Feedstock	Feedstock + co-product
Sugarcane	Source: CONAB (2012)		Data for: cane stalk, optimized yield (South-Centre Region)	Data for: recoverable sugar (TRS)	Data for: TRS, bagasse and trash (50% collection)
Soybeans	Source: IBGE (2013)		Data for: bean	Data for: soy oil	Data for: soy oil an meal
Corn	Source IBGE (2013) Data for: 1st and 2nd crops		Data for: grain	Data for: grain USDA	Data for: grain and DDGS USDA
Cassava	Source: IBGE (2013)		Data for: roots (optimized yield)	Data for: roots	Data for: roots and plant
Sorghum (sweet)	Currently there is not commercial production in Brazil		Source: CERES (estimated)	Data: fermentable sugar	Data: fermentable sugar
Peanut	Source IBGE (2013)		Data for: optimized yield	Data for: peanut oil	Data for: peanut oil and meal
Castor bean				Data for: castor oil	
Sunflower seed				Data for: sunflowers oil	Data for: sunflowers oil and meal
Camelina	Currently there is not commercial production in Brazil			Data for: camelina oil	Data for: camelina oil and meal
Palm	Source: IBGE (2013) Production data for: fresh fruit bunches (FFB)			Data for: palm oil	Data for: palm oil, palm kernel oil and ampty bunches
Jatropha	Currently there is not commercial production in Brazil			Data for: jatropha oil	Data for: jatropha oil and cake
Elephant grass			Source: Embrapa Agrobiologia Data in: ton of dry matter (leaves and sterns)	Currently it is not applied	Data for: whole plant
Eucalyptus	Source: ABRAF (2012) Production data in: m^3		Source: ABRAF (2012) Data in: m^3/ha/year (mean annual increment)		Data for: whole tree, including bark
Pinus					Data for: whole tree, not including bark

PRODUCER PRICE	PRODUCTION COST		ENERGY BALANCE	GHG	
				EMISSION	SAVING
unit.	unit.	unit.	unit.	unit.	unit.
Data for: Consecana (2013)	Source: Agrianual (2012) Data for: São Paulo State		Source: Nassar and Cantarella (2012b)	Source: EU (2009) Data for: ethanol from sugarcane	
Source: Agrianual (2012)	Source: Agrianual (2012) Data for: Parana State, GMO		Source: Nassar and Cantarella (2012b)	Source: EU (2009) Data for: biodiesel from soybean	
	Source: Agrianual (2012) Data for: 2nd crop		Not available	Source: EU (2009) Data for: ethanol from corn	
Source: Agrianual (2012)			Source: Nassar and Cantarella (2012b)	Source: Nguyen et al. (2007) Data for: ethanol from cassava	
Not available	Not available	Not available	Not available	Not available	
Source: Agrianual (2012)			Not available	Not available	
Source: Agrianual (2012)			Not available	Not available	
Source: Agrianual (2012)			Not available	Source: EU (2009) Data for: biodiesel from sunflower seed	
Not available	Not available	Not available	Source: Nassar and Cantarella (2012b)	Source: SWAFEA (2011) Data for: biodiesel from camelina	
Source: Agrianual (2012) Data in: R$/t FFB	Source: Agrianual (2012) Data for: average of 20 years		Source: Nassar and Cantarella (2012b)	Source EU (2009) Data for: biodiesel from palm fruit	
Source: Agrianual (2012)	Source: Agrianual (2012) Data for: average of 15 years		Source: Nassar and Cantarella (2012b)	Source: SWAFEA (2011) Data for: biodiesel from jatropha	
Not available	Not available	Not available	Source: Nassar and Cantarella (2012b)	Source: SWAFEA (2011) Data for: switchgrass	
Source: Agrianual (2012) Data: not included harvest and handlling	Source: Agrianual (2012) Data for: average of 14 years and not included harvest and handlling		Source: Nassar and Cantarella (2012b)	Source: EU (2009) Data for: biodiesel from wood waste	
Not available	Not available	Not available	Not available	Not available	

Planted forests may be grown in hilly terrain, not suitable for row crops, and, many times considered as marginal land. Forests have a long harvesting season and their products may be stored for long time. Importantly, forests may increase carbon storage in the soil thus representing a further mitigation of CO_2 emission, in addition to the replacement of fossil fuel by the biofuel produced.

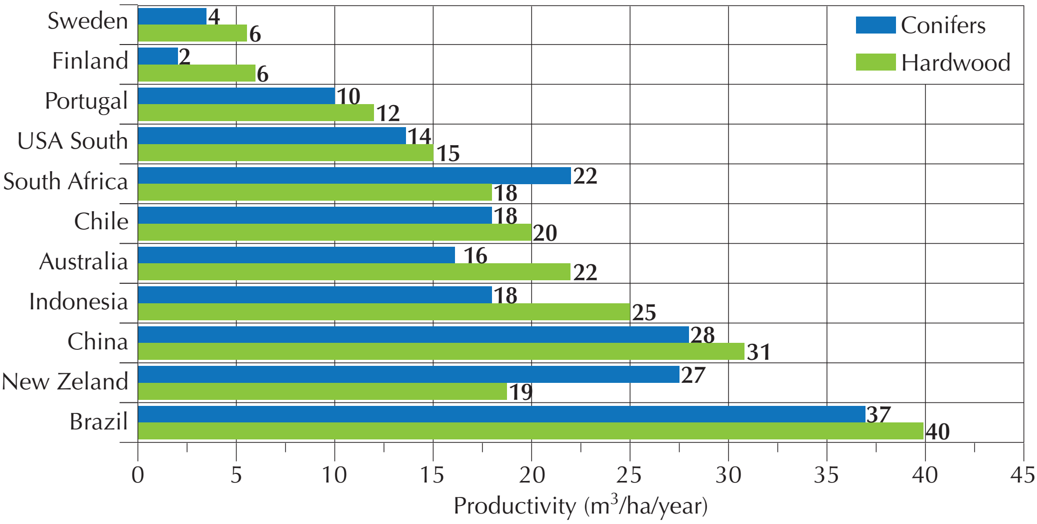


Figure 26 Yields of planted forests in several countries. Source: ABRAF, 2012.

Sugarcane is in a very favorable position both in terms of energy yield and GHGs emissions. Sugarcane is grown in more than 9 Mha in Brazil, where it has being used as a feedstock for biofuel for many decades and has an important production and research infrastructure (CANTARELLA et al., 2012). Elephant grass (*Pennisetum purpureum* Schum) as well as other tropical grasses are cultivated as grazing plants but there are also varieties that are suitable as a biofuel feedstock (MORAIS et al., 2009). Elephant grass also has good numbers as to the reduction of GHGs emission.

Yields of both biomass and energy of oil crops are somewhat lower than those of grasses and wood, but they are also suitable feedstocks for jet biofuel. Brazil has already a mandate to produce biodiesel (5% maximum blended to the diesel) and presently this fuel is derived from renewable sources (85% vegetal oils and 15% animal fats). Most of the biodiesel in Brazil is made with soybean because this crop is extensively cultivated, has high yields and competitive prices (although government subsidies are in place). When the biodiesel program started in Brazil castor bean was one of the target crops because it could be cultivated by small farmers of poor regions but production costs, scale and logistics were not favorable. This is a limitation that may apply to other oil crops but, notwithstanding, many oil producing species are potential feedstock for jet fuel.

The competitiveness of the different feedstocks against jet fuel prices in Brazil is presented in **Figure 27a**. The opportunity costs on are expressed in US$/GJ. Energy yields and prices for the feedstocks were the same as in **Table 6**. The first graph presents the opportunity costs departing from the agricultural product, while in the second the departing product is the main final product of the feedstock, including the biofuel in specific cases (ethanol from sugarcane, for example).

Intuitively, the difference between the opportunity cost of the final product and the agricultural product is the value added of the industrialization, including processing costs. The assumptions are presented below the figure. The intention of this figure is to show that the opportunity costs of feedstocks are high in comparison with aviation kerosene prices in Brazil.

The opportunity costs of feedstocks changes with time due to price fluctuations. Data from 2012 indicate that all feedstocks considered, excluding soy bean, have lower cost per unit of energy than aviation kerosene (**Figure 27a**). However, when the comparison is done taking into account the final products, only bagasse and wood have lower cost per unit of energy than aviation kerosene. Palm oil, anhydrous ethanol and soybean oil have prices slightly higher but, eventually can also be competitive, whereas the use of sugar and cassava for production of aviation kerosene will hardly be justifiable due to the more favorable price if directed to the sugar and cassava flour market. The need for a special tax treatment for jet biofuels in order for the aviation industry to decrease carbon emission and have more sustainable fuels was a conclusion reported in the Sustainable Aviation Fuels Northwest (SAFN, 2011). **Figure 27b** indicates that a special treatment is also necessary to allow the development of the jet biofuel production in Brazil.

The definition of policies make sense environmentally because biofuels have a potential to reduce GHG emissions, which is one key objective pursued by the aviation industry. That price comparison shows that reducing production cost is also a central objective to allow biofuels to become more competitive. It should be also considered that prices of petroleum-derived fuels are likely to increase in the future.

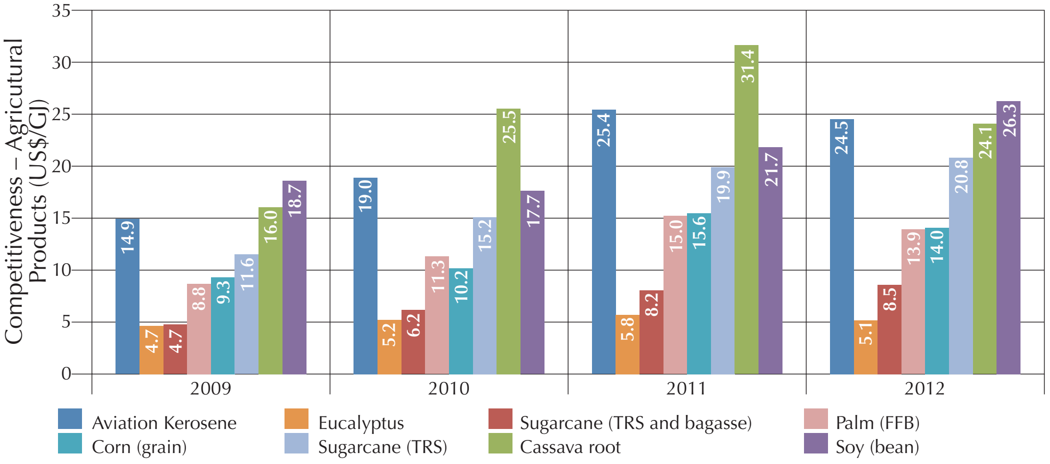


Figure 27a Feedstocks and Jet Fuels: Competitiveness (US$/GJ) – Agricultural products and Final products.

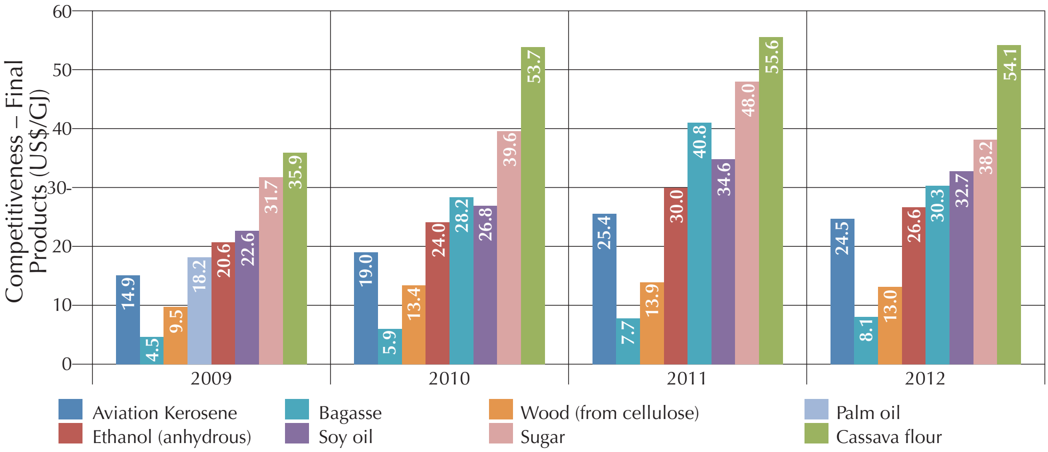


Figure 27b Feedstocks and Jet Fuels: Competitiveness (US$/GJ) – Agricultural products and Final products.

Parameters:

- Biodiesel: 37.5 MJ/kg; Ethanol: 21.2 MJ/liter; TRS Ethanol: 1.77 kg/liter; TRS sugar: 1.04 kg/kg; Eucaliptus wood/pulp: 4 m^3/ton; Eucaliptus density: 0.6 kg/m^3; Eucaliptus:12.98 MJ/kg (30% humidity); Cassava (root): 210.5 liter ethanol/ton; Cassava flour: 300 kg/ton of cassava root; Bagasse (only electricity sugar): 296.4 kWh/ton bagasse; Bagasse (total energy): 1240 kWh/ton bagasse; Sugarcane: 81.5 liters ethanol/ton; Sugarcane: 64.6 kg ethanol/ton; Sugarcane: 280 kg bagasse/ton; Jet fuel: 34.4 MJ/liter; Soy: 190 kg oil/ton; Soy: 790 kg meal/ton; Soy meal: 15.4 MJ/kg; Corn: 412.8 liters ethanol/ton; Corn DDGS: 303.2 kg DDGS/ton; Soy: 190 kg biodiesel/ton; Soy: 19291 MJ/kg; Bagasse: 8.9 MJ/kg (50% humidity); Sugarcane: 4225.4 MJ/ton; Corn DDGS: 18.4 MJ/kg; Corn: 14318 MJ/ton; Palm (FFB): 220 kg oil/ton FFB, 25 kg palmiste oil/ton FFB, 220 kg cake/ton FFB, 9,188 MJ/kg.

4.1.1.1 Feedstock groups

In this study, the feedstocks were separated into four groups according to the nature of the compounds used for transformation: sucrose/starch (sugarcane, sweet sorghum, cassava and algae), oil-bearing feedsocks (soybean, palm, castor beans, jatropha, camelina, sunflower, rapeseed, peanut, other native palm trees and photosynthetic algae), cellulosic (grasses, forestry wood residues, forestry industrial residues, cane bagasse, agricultural residues) and wastes (flue gas, MSW, used cooking oil, tallow and sewage).

Table 7 brings a summary of the main technological areas, technologies or process which requires R&D efforts, as pointed out in the presentations of the feedstock experts.

Sources, Bases and Prices: Agricultural products & Final products:

AGRICULTURAL	Unit	Source	Base	2009	2010	2011	2012
Sugarcane	R$/ton	Consecana/UNICA	delivered at mill	39.9	46.4	57.7	70.3
Cassava	R$/ton	IEA/São Paulo State	farm gate	142.4	200.6	234.9	210.5
Soy	R$/ton	DERAL/Parana State	farm gate	720.3	599.2	701.4	990.2
Corn	R$/ton	DERAL/Parana State	farm gate	267.0	256.7	373.5	392.0
Eucalyptus	R$/$m^3$	IEA/SP, including harvest and handling	delivered at mill	72.4	71.9	75.4	78.1
Palm (FFB)	R$/ton	Agrianual/FNP	delivered at mill	161.0	183.0	230.0	250.0

FINAL	Unit	Source	Base	2009	2010	2011	2012
Palm Oil	US$/ton	CME Group	world price	682.8	900.8	1,125.4	999.3
Soy oil	US$/ton	CME Group/CBOT	world price	848.7	1,004.6	1,299.3	1,226.3
Sugar	US$ cents/ pound	CME GROUP/NYMEX	world price	394.7	492.9	598.5	475.8
Ethanol (anhydrous, sugarcane)	R$/liter	ESALQ/CEPEA	ex-factory price	0.9	1.1	1.4	1.3
Cellulose	US$/ton	SECEX/MDIC	export price	385.8	541.1	563.1	527.0
Wood (from cellulose)	US$/$m^3$		derivated from cellulose	96.5	135.3	140.8	131.7
Cassava flour	R$/ton	IEA/São Paulo State	whole sale price	1,066.4	1,406.5	1,385.2	1,571.3
Electricity	R$/MWh	Empresa de Pesquisa Energetica	auction price	134.0	138.5	145.0	144.0
Bagasse (total energy)	R$/ton		derivated from electricity	166.2	171.7	179.8	178.6
Bagasse (only electricity surplus)	R$/ton		derivated from electricity	39.7	41.1	43.0	42.7
Bagasse	R$/ton		Same price of sugar	39.9	46.4	57.7	70.3
Aviation Kerosene	R$/liter	ANP/Federal Government		1.0	1.1	1.5	1.7

Exchange rate	R$/US$		2.00	1.76	1.67	1.95	

Table 7 Main limitations and areas for which research and technological development are needed to increase feedstock feasibility for jet biofuel production.

PRODUCTS	RELEVANT TECHNOLOGICAL AREAS, TECHNOLOGIES OR PROCESSES
Soybean	• Improve crop management • Genetic improvement - Improve drought tolerance - Increase oil content - Decrease the use of agrochemicals for pest and disease control • Decrease harvest and storage losses, and transportation costs, through better logistics and more efficient machines • Improve GHG performance
Palm	• Strengthen breeding program • Improve or develop varieties with resistance to Bud Rot • Develop high efficiency cloning system • Increase seed production • Reduce production cost • R&D and strengthening of the production chain
Camelina	• Introduction of a new crop to local growers • Adapt camelina variety to local conditions • Definition of the optimized camelina planting protocol • Determine camelina sustainability, including LCA analysis • Agricultural machinery, crushing facilities availability, logistics and transportation
Jatropha	• R&D and strengthening of the production chain • Definition of a production system • Broaden genetic diversity (plant breeding), • Develop suitable cultivars; solve problems of uneven fruit ripening, toxicity of the biomass residuals • Reduce production cost • Develop mechanical harvest: machines, as well as adapt the plants for it
Sugarcane	• Decrease cost of harvesting and transportation • Improve planting practices (decrease seed use, improve yields etc) • Competition for other energy sectors (electricity, ethanol from 2nd generation, others) • Increase investment in plant breeding: varieties for new frontiers of cultivation; drought tolerance 1. Transgenic varieties • Adoption of precision agriculture to increase overall efficiency (increase yields, increase plant longevity, improve GHG and energy balances) • Improve nitrogen fixation • Improve recycling of nutrients
Sweet sorghum	• Plant breeding for increased yield and development of hybrids with different photoperiod response • Plant breeding for extended harvest period. • Deployment of transgenic sorghum, regulatory issues • Minimum/reduced tillage planting to protect soil and provide better crop development • Industrial processing of sugar and starch (grain)

Table 7 Main limitations and areas for which research and technological development are needed to increase feedstock feasibility for jet biofuel production (continued).

PRODUCTS	Relevant technological areas, technologies or processes
Cassava	• Increase general investment in the crop (few scientists working on this crop) • Development of new varieties for the production of energy and greater exploration of the interaction genotype environment • Development of more efficient production systems based on crop rotation and consortium • Rationalization of fertilization • Development of machines for harvesting • Improve industrial development for processing feedstock for biofuel production Uncertainties related to efficiency and supply of enzymes
Eucalyptus	• Improve plant breeding, especially to meet needs of new planting frontiers and drought tolerance • Adapt plants and crop management to future climatic and economic uncertainties • Improve harvesting and transportation systems, specially for forest residues
Grasses	• Breeding and selection of genotypes of high biomass yield for each edaphoclimatic condition • Improve the biological fixation of nitrogen (BNF) characteristics in new hybrids and varieties • Optimize the use of nutrients, specially N and K • Improve cutting, collection, and drying of large quantities of biomass • Develop better strategies for stocking and processing large quantities of plant biomass
Plant residues	• Decrease cost of collection and transportation • Develop strategies for minimizing the effect of organic matter and nutrient removal from the field
Solid waste	• High feedstock volume required for large scale production • Transition from compost or anaerobic digestion to biofuel plant • Biogenic municipal solid waste (MSW) collection costs must be competitive with current costs • Environmental legislation constraints: air permit; solid waste permit
Flue gas	• Scaling up the technology • Feedstocks used are point sourced, available in high volumes with low intrinsic value and are non food • Increase efficiency through integrated systems • Expanding range of usable gas streams
Algae (sugar)	• Scaling up the technology • Need to widen the variety of inputs to feed to algae (sugar, starch and cellulosic ethanol) • Need of LCA analysis

It is clear that each feedstock has specific problems and challenges and the specialists may have used different approaches to select priorities. Although some technologies were quoted in several cases, such as plant breeding, current knowledge on feedstocks is very different. In addition, specific challenges are related to characteristics such as production cycle (annual crops vs. perennial crops), use as food, or the waste nature of the feedstock. Their challenges, therefore, must be considered individually.

In general, for all cultivated crops, continuous genetic improvement through plant breeding is an important tool to increase yield, adapt plants to different regions or environments, improve plant resistance or tolerance to pests and diseases, improve plant quality for processing for biofuel production, increase drought tolerance, nutrient use efficiency, and many other useful traits. Crops such as soybean, sugarcane, and eucalyptus have already a solid research base in Brazil so that the knowledge baseline is high; therefore, R&D results can come relatively fast but gains will not be significant in the short term. Modern molecular biology tools and transgenics may be important for these crops (**Table 7**).

Other crops with some tradition in Brazil are in an intermediate level of technological development, but may have substantial gaps concerning their use as biofuel feedstock, including cost and competitiveness: peanuts, sunflower, castor bean, cassava. Sorghum is a relatively known crop in Brazil but its use as a source of sugar is of little significance so far; therefore, the research effort in this case is relatively high. The infrastructure and critical mass of research in Brazil is good for these crops, so progress is expected.

Palm has specific needs because of its high water and temperature requirements (**Table 7**); it is suitable, with present technology, only to the Northern Brazil forest areas. An agroecological zoning for palm plants in the already cleared lands of the Amazon was recently proposed (EMBRAPA, 2010), highlighting the environmental, economic and social benefits that this crop can bring to the region. The research infrastructure is relatively small and need expansion.

Other crops that could be used as jet biofuel have a small research base in Brazil. These are the cases of jatropha and camelina.

Jatropha curcas is a perennial crop whose seeds contain large amounts of oil that can have many uses, including the production of biofuel. Jatropha has been inadequately promoted as an oil crop capable of reaching high seed yields in low fertility soils, with very little fertilizer needs, tolerant to drought, diseases and pests, and suitable to be grown in marginal areas – promotion that seems rather premature since Jatropha still has several hurdles to be overcome through R&D. Its cultivation has been stimulated in many places in order to produce oil for biofuels and other uses. In 2008 an estimated 900 thousand hectares of jatropha was cultivated worldwide, most of it in Asia (KANT; WU, 2011). However, reports of crop failure to meet the initial expectancy are common. Probably, the most critical case of failure was in India (OPENSHAW, 2000; KANT; WU, 2011; KUMAR et al., 2012), where the Government promoted the cultivation of jatropha by smallholders to meet most of the needs of an audacious program to reach a 30% blending of biodiesel by 2020 (KANT; WU, 2011). Most farmers have discontinued cropping after some time (AXELSSON et al., 2011). Unfavorable results were also reported in other countries in Asia and Africa (KANT; WU, 2011; MUBONDERI, 2012). The same happened in Brazil. For instance, about 1200 ha of jatropha was planted in 2007 at Ribas do Rio Pardo, MS, but most of the plants were removed after sometime, although experimental efforts still continue (CANTARELLA, 2013b).

Even the authors of critical reports on jatropha failures usually agree that this crop has potential as a source of vegetal oil. However, several limitations must be overcome. There is a need of improved varieties (for high yields, pest and disease tolerance, adapted to different regions, uniform flowering and production to allow mechanical harvest), development or adaptation of harvesting machines, and use of co-products (**Table 7**). Berenchtein et al. (2010) reported that jatropha meal detoxified during oil extraction could be used as animal feed, thus increasing the value of the whole crop.

The challenges of turning jatropha into a viable alternative for biofuel production are being addressed by several public and private institutions. For instance Seeds Genomics Biofuels (SGB), an energy company headquartered in San Diego, CA, is using modern biotechnology tools to develop and speed up the production of new hybrids from a wide collection of germplasm (12 thousand genotypes) and testing them in several countries and regions within countries, including Brazil. SGB is also perfecting agronomic practices to obtain high yields, based on the use of fertilizers and agrochemicals and not in the "miracle-plant" concept that characterized the early attempts to promote jatropha (CANTARELLA, 2013b). Several institutions in Brazil (Embrapa and the Agronomic Institute of Campinas) and in the world are also making efforts to improve jatropha. SGB and Embrapa are planning to work together to advance jatropha research. However, much work remains to be done with this crop.

Camelina is a crop that has no tradition in Brazil so far, but, its use as feedstock for jet biofuel will benefit from the investments and developments of the other oil crops. It has lower yields than jatropha but has a short cycle and both its oil and meal can have other uses. It can be grown as a second crop in the same season, similarly to peanut, sunflower, and other plants, which can minimize the completition with food production. Camelina's opportunity cost and relatively low GHGs and energy balances may hinder its use as a feedstock for jet biofuel (**Table 7**). Camelina lacks the critical mass and research infrastructure of other crops already grown in Brazil so its adoption as a cultivated crop may take longer. However, camelina may take advantage of the research expertise in other countries to make up for the knowledge gap under Brazilian conditions. For instance, The Camelina Co, based in the USA, is developing agronomic technology and camelina varieties in partnership with research institutions in North America. Camelina is presently cultivated in 20 thousand ha in the dry lands of Northern USA in rotation with cereals. Sizeable areas are also grown in Canada (MOSER, 2010). Camelina España is promoting this crop in the dry lands of Spain, where it expects to reach 15 thousand ha in 2013-2014 (CANTARELLA, 2013a). In both North America and Spain camelina is considered a non-food crop, although its oil is rich in omega-3 fatty acids, an interesting trait for the food industry. In Brazil, BIOECA is testing camelina as a second crop in succession with the summer crops, taking advantage of this crop's drought tolerance. Much work remains to be done in order to select varieties and adapt agronomic technologies but camelina may become an option of oil crop for the second season, depending on oil yields and price. Similarly to jatropha, an adequate supply chain needs to be established.

Many tropical grasses can be used to produce bioenergy but most of the studies with these plants have been done for pasture or animal feed production. Despite the high yield potential, limitations for their use as biofuel include the high fertilizer requirements to produce optimum yields, the costs of collection, transportation and storage, and the GHGs and energy balances (**Table 7**). Morais et al. (2009) have identified varieties of elephant grass that are suitable for bioenergy production.

Algae are also potential producers of jet biofuel, both as source of oil through photosynthesis or transformation of sugars, starch or other compounds directly into biofuels. Despite the huge potential for oil production per unit area of photosynthetic algae, the cost and operational problems seem to be too high at present. Other limitations for jet fuel production from algae were discussed at the SAFN (2011). The photosynthetic algae option is acknowledged but it was not included in the present report because of the enormous R&D needed. Technologies for transformation of sugars, starch, ethanol etc into biofuel exist but need scaling up. In this case, the feedstock is the raw material to feed the algae (i.e. sugar), and it was treated with their respective source (**Table 7**).

Wastes and residues are very convenient feedstock for jet biofuel because the benefits are two-fold: they do not compete with food production for land or other resources and their use avoids or decreases the cost and impact of their disposal into the environment. Wastes and residues are also widely available and in many cases are point sourced so there is no requirement to develop dedicated feedstock production infrastructure.

There are plenty of options of plant residues in Brazil because of its large agricultural production, including those of grain and perennial crops. Probably the plant residues available in the largest amounts are those of sugarcane, especially bagasse, but also harvest residues, composed of leaves and tops (ROSSETTO et al., 2010; MAGALHÃES et al., 2012). Bagasse, which is generated from the crushing of sugarcane for sugar or ethanol production at a rate of 250 kg (50% moist) per tonne of sugarcane processed (MAGALHÃES et al., 2012), has the advantage of being available at the mill, meaning that the cost of collection and transportation is generally allocated to sugar or ethanol costs. However, bagasse is already used to produce vapor power and electricity to run the mill and surpluses may be sold as bagasse or energy to the grid. Today, almost 6% of the electricity in Brazil comes from plants burning sugarcane bagasse, hence, it has already a market value. However, only 30% of the sugar and ethanol mills sell electricity, indicating that if current furnace efficiency is increased, there may be a surplus of bagasse for other uses. If second or third generation biofuel (or specially jet biofuel) can compete pricewise with other uses for bagasse, there is already a huge amount of feedstock.

Crop residues that have to be collected from the field are also abundant, especially for sugarcane. The amounts of leaves and tops that remain in the field after sugarcane harvest vary from 8 to 20 t/ha of dry matter. Modern grain crops usually have a harvest index around 40 to 50% (40 to 50% of the dry matter is grain); therefore, large amounts of plant material are left behind the grain harvest (CLAY et al., 2012). Two important aspects of crop residues that need studies and technological developments are the cost of collection plus transport and the definition of how much residue to leave on the soil (**Table 7**). Operations of field collection and transport are significant components of overall feedstock cost because plant residues have low density and low unit price (MAGALHÃES et al., 2012). In addition, not all plant residues should be harvested for fuel production because soil organic matter reposition is essential for long term soil quality preservation as well as nutrient recycling, usually a site-specific problem (CANTARELLA et al., 2012; CANTARELLA; ROSSETO, 2010; CLAY et al., 2012).

Forest residues are also options of feedstock (see Logistics, ahead) because of the high volumes of plant material left after round wood is harvested. The limitations of cost of collection and definition of how much organic material to leave on the soil also apply here.

Urban wastes are plentiful because cities are the destination of most of the agricultural products including food, paper and packing, and other raw materials. This is an advantage because these wastes may be available at or near the site of processing and use of the bioenergy. Wastes may have negative price because their producers usually pay for their disposal and the cost of landfills are increasingly high almost everywhere. However, wastes are heterogeneous material, the cost of separation and processing are normally high and there may be environmental legislation constraints that must be addressed (**Table 7**).

4.1.1.2 Sustainability issues

The 4th Workshop – "Sustainability" – aimed to enhance the discussion on aspects of sustainability of biofuels for aviation, related to environmental, social, economic, and institutional aspects.

The main topics presented and discussed in the 4th Workshop were: energy balance; greenhouse gases emissions; productivity; agricultural and environmental best practices: fertilizer consumption, consumption of pesticides, soil loss, water use; biodiversity; energy self-sufficiency; social, economic, institutional environment aspects: legislation, and regulations.

It is important to assess central sustainability aspects related to the production and adoption of jet biofuels, such as GHG reduction potential and the capacity of supply chains to comply with sustainability standards and national social and environmental laws, as well as the economic aspects related to this.

In the 4th Workshop the gaps of supply chains to meet the sustainability requirements were identified and discussed, as well as the impacts of the compliance of the sustainability requirements on financial, technical and commercial risks.

The theme of sustainability is growing in importance in recent years, especially in a scenario with the need for reduction of greenhouse gases emissions, the food versus fuel debate, and the increasing need to meet environmental and social standards.

The plausible feedstock identified in previous workshops (namely sucrose, oils, cellulosic, and waste) were analyzed according to the most known sustainability criteria. The analysis included, although was not limited to, the evaluation of some parameters (when data is available): (i) Potential of CO_2 net reduction per ha; (ii) Land use change (LUC and ILUC); (iii) GHG emissions; (iv) Food security; (iv) Water Use; (vi) Technical skills of rural workers in feedstock value chain; (vii) Mean income per rural worker; (vii) Labor intensity; (viii) Mechanization of planting and harvesting; (ix) Use of agrochemicals; (x) Pollution.

The principles stated in RSB (2010) illustrate the main requirements related to biofuel production when analyzing sustainability aspects (**Table 8**), and were used in the groups discussion with the stockholders in the Workshop. In order to select a set of parameters in the three sustainability pillars (economic, social and environmental), the principle and criteria of three sustainability standards, not coincidentally the ones most used for biofuels, were used as reference. They were Bonsucro, RSB and ISCC and the selection was based in ICONE (2012).

There is a demand in Brazil and worldwide by agricultural practices that are both economically and socially sustainable, which has motivated efforts and investments of producers. Due to this, private sustainability standards and certification schemes have become developed by initiatives such as Bonsucro, the Roundtable on Sustainable Biomaterials (RSB), the Roundtable on Responsible Soy (RTRS), and the Roundtable on Sustainable Palm Oil (RSPO), became common in the market over the past years, as a way of improving and demonstrating the sustainability of the production chain.

The aviation industry will most likely require a sustainability certification for the production of jet biofuels, including feedstocks production, in order to the guarantee that such fuels are produced in compliance with environmental and social requirements determined through a multi-stakeholder process.

Table 8 Principles that should be followed for biofuel production according to Goldemberg (2011).

1	**Legality**	Biofuel operations shall follow all applicable laws and regulations.
2	**Planning, Monitoring and Continuous Improvement**	- Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis; - Biofuel operations shall undertake an impact assessment process to assess impacts and risks and ensure sustainability through the development of effective and efficient implementation, mitigation, monitoring and evaluation plans; - Free, Prior & Informed Consent (FPIC) shall form the basis for the process to be followed during all stakeholder consultation, which shall be gender sensitive and result in consensus-driven negotiated agreements.
3	**Greenhouse Gas Emissions**	Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels.
4	**Human and Labor Rights**	Biofuel operations shall not violate human rights or labor rights, and shall promote decent work and the well-being of workers.
5	**Rural and Social Development**	In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.
6	**Local Food Security**	Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.
7	**Conservation**	Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values.
8	**Soil**	Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.
9	**Water**	Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.
10	**Air**	Air pollution from biofuel operations shall be minimized along the supply chain.
11	**Use of Technology, Inputs, and Management of Waste**	The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people.
12	**Land Rights**	Biofuel operations shall respect land rights and land use rights.

These sustainability certifications are focused especially on GHG emissions reductions, other environmental impacts (such as water and biodiversity), and minimization of socio-economic impacts. These standards address similar sustainability issues, and a comparison among them can be found in the WWF, IUCN and NRDC reports (WWF, 2013; IUCN, 2013; NRDC, 2014). They all require compliance with the currently available national law and most well known international sustainability standards for biofuels production, namely Bonsucro, Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification System (ISCC).

Broadly, most criteria are related to indirect impacts, such as food security, Indirect Land Use Change (ILUC) and biodiversity. These additional criteria are associated to complex issues that are still being extensively discussed. There are no widely accepted methodologies to address them, which complicates even more their inclusion into the standards, which ends up being done in a very conservative manner.

It is important to discuss these issues, since sustainability certification will increasingly become a requirement for accessing markets and since the standards and certification processes are complex and require adaptations of the supply chain. While they may generate benefits for producers and processors, they may also generate additional costs and hurdles. It is fundamental to understand the differences between the standards and the gaps to compliance when considering the context and opportunities for jet biofuel production in Brazil.

To define the Sustainability requirements to be analyzed during the 4th Workshop a recent report released by ICONE (2012) on sustainability private standards was taken into account. ICONE carried out a benchmark study to assess the main differences between three standards for certification of biofuels (Bonsucro, RSB, and ISCC) and to identify the main gaps for compliance with these standards in Brazil. Although the study was focused on a jet biofuel produced from sugarcane, many of the issues identified are common to the whole agricultural sector, among them compliance with the Brazilian laws, especially those on environment, labor and worker health and safety. There are other gaps that go beyond the law, especially those related to the interpretation and implementation of certain criteria, such as Human Capital Value Added (HCVA), ILUC and food security.

4.1.2 Feedstock logistics

Logistics of feedstocks plays a very important role in biofuels sustainability since it greatly affects costs and CO_2 emissions. In order to discuss in more detail the logistics to produce biofuels for aviation in Brazil three feedstocks were selected due to their present importance in Brazilian agriculture: soybean, sugarcane, and wood.

Each of these three feedstocks present different characteristics that make them unique as far as logistics is concerned. Particularly bulk density, harvest seasonality and storage capacity are critical factors affecting plant supply. Therefore, logistics may greatly affect jet biofuel manufacturing plant size and the entire economics of biofuels. **Table 9** presents a brief comparison considering soybean, sugarcane, and wood.

Table 9 Feedstock characteristics affecting logistics for biofuels production.

ITEM	FEEDSTOCK		
	SOYBEAN	SUGARCANE	WOOD (EUCALYPTUS AND PINE)
Feedstock characteristic	Grains	Stalks and leaves	Logs, charcoal, firewood, forest residues
Present feedstock logistics	Transport harvested grains to oil extraction plants (up to thousands km)	Transport harvested cane stalks and leaves to the mill (up to 50 km; avg 40 km)	Transport harvested wood to the mill (avg 88 km)
Relative importance of feedstock cost and logistics in final biofuels cost	High (~90% of biodiesel)	High (~60-70% of ethanol)	Low (~30% of synthetic FT biofuels)
Average Yield	2-3.5 tons of grains/ha.year	60-100 tons of cane stalks/ha.year	45 tons of wood/ha.year
Feedstock bulk density	High (~450-500 kg/m^3)	Low (~200 kg/m^3)	Medium-High (~400 kg/m^3)
Feedstock Moisture Content	Low (~12% d.b.)	High (~70% d.b.)	Medium (~40-50% d.b.)
Harvest Season	Jan - May	April-November in Central South Brazil	All year, except rainy days
Need to be processed after harvest	No immediate need, if dried	Needs to be processed with 24-48h after harvest	No immediate need, if dried
Storability	Very high	Difficult. An alternative is Sucrose concentration and fiber densification	High. L logs are very easily stored, residues can be compressed
Importance in Brazilian Food Market (Domestic and Exports)	High	High	None
Importance in Brazilian Energy Matrix	Low (only biodiesel ~1%)	High (~20%)	High (~10%)
Total annual production	70 million tons	650 million tons	254 million m^3

These three crops (soybean, sugarcane, and wood) are cultivated in Brazil in large scale. Typically a Brazilian farm for these crops can reach several thousand hectares but can also be a small to medium size farm. The main reason for using large scale production systems are the gains associated with scale, such as cost reduction, possible with centralized management.

Soybean

Soybean is the most important grain produced in Brazil followed by corn. In 2013-2014 around 90 million tons are expected to be harvested. Although soybean cannot be considered an energy crop, around 80% of biodiesel produced in Brazil (around 2.5 billion liters) used soybean as feedstock. The present prices paid for biodiesel – including subsidies – in Brazil to guarantee B5 turn the use of soybean for biofuels economically viable. However, this scenario doesn't seem to be sustainable for B10 because, under current diesel prices, subsidies would be costly.

Soybean started to be cultivated in Brazil in the early seventies in the Southern states of Rio Grande do Sul and Paraná. Later, this crop spread from north to west to São Paulo, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Goiás, Rondônia and Bahia. The **Figure 28** presents the main soybean producing areas in Brazil highlighting the agroindustrial plants.

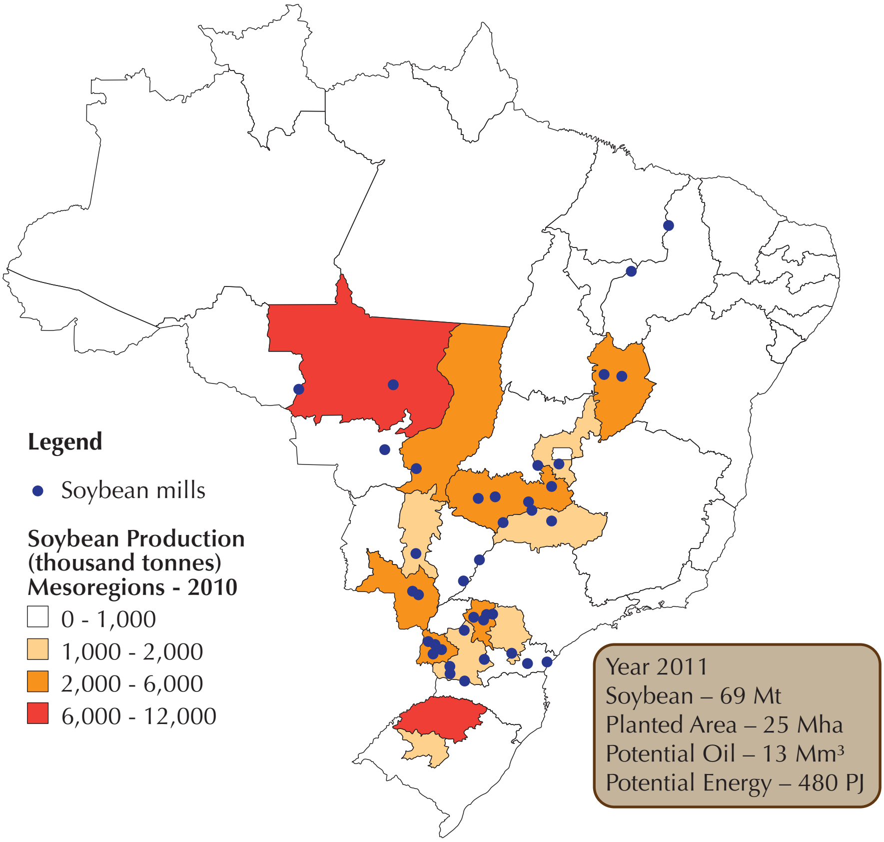


Figure 28 Map of production areas and location of mills of soybean in Brazil. Source: ESALQ-LOG apud Nunes, 2012.

Soybean grains are transported from the agricultural fields basically to two destinations: agroindustrial plants, where the grains are crushed, and harbors from where the grains are exported. Since soybean presents a relatively high bulk density and is easily stored it can be transported to long distances by trucks, trains and ships.

In Brazil there are basically the following corridors for soybean transportation:

1. The south involving soybean grains produced in the southern states of Rio Grande do Sul and Paraná and Central West states of Mato Grosso do Sul, Mato Grosso, Minas Gerais and Goiás. The soybeans grains are transported by truck to Paranaguá harbor located in the Paraná state and then exported mostly to Europe and China. Other harbors used are those of Paranaguá, in Paraná and Santos, in São Paulo
2. The North corridor involving basically Mato Grosso state. The soybean grains are transported by truck to Itacoatiara, AM, and Santarém, PA harbors. Large ships can access these harbors and go directly to Europe and China.
3. The so called "new agricultural frontier", also in the North of the country, specifically West Bahia and the states of Maranhão, Piaui and Tocantins, which is transported by trucks through the Bahia port of Aratu or through the Itaqui port in Maranhão. For this last corridor, the North-South Railway has also been used.

The Brazilian transportation infrastructure, composed by roads, railroads and waterways are considered a major obstacle for efficient and low cost soybean grain long distance hauling. **Figure 29** shows the existing road and waterway system in Brazil. The Brazilian federal government has plans to invest in the railway system to facilitate cargo transportation. **Figure 29c** indicates the possibilities in this area

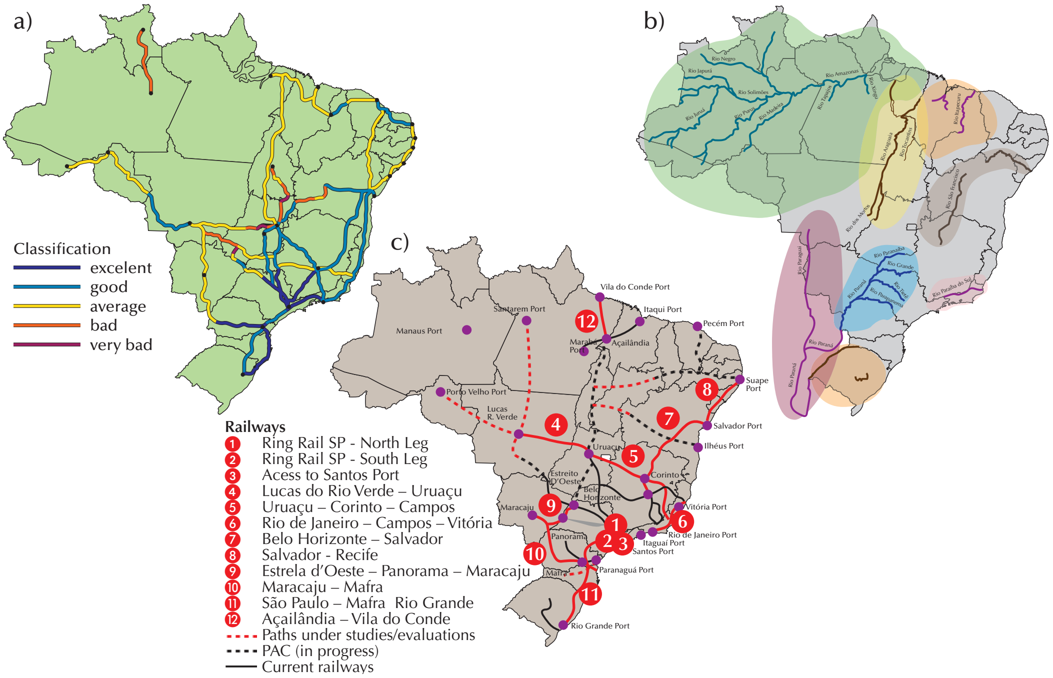


Figure 29 (a) Roads usually considered for the transportation of soybean in Brazil and their state of conservation. Source: CNT apud Nunes, 2012. (b) Main watersheds and rivers used for the transportation of commodities in Brazil. Source: ESALQ-LOG apud Nunes, 2012. (c) Railroad system in Brazil: existing grid and planned. Source: Brasil nos Trilhos apud Nunes, 2012.

Since soybean is cultivated in many regions in Brazil, the infrastructure as well as the limitations described for soybeans also apply to other similar feedstocks that can be used for jet biofuel production.

Sugarcane

Sugarcane is produced in Brazil basically in two areas: Northeast coast (RN, PB, PE, SE, AL states) responding for ~10% of production and Central-South (SP, PR, MS, MT, GO, MG and RJ) responding for ~90% of production. **Figure 30** presents (a) the current sugarcane producing areas in Central-South Brazil and (b) potential sugarcane producing areas in Brazil.

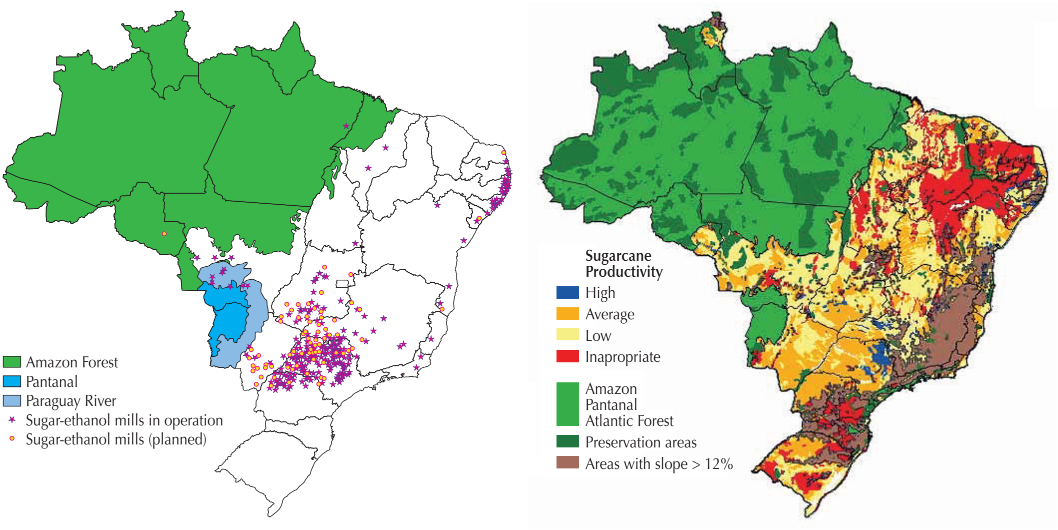


Figure 30 (a) the present sugarcane producing areas in Central-South Brazil. Source: EMBRAPA, 2009. (b) potential sugarcane producing areas with expected yields in Brazil. Source: CGEE, 2009.

The possible sugarcane feedstocks are: sugarcane stalks, sugarcane bagasse, tops and leaves, and ethanol. Important characteristics for sugarcane-derived feedstocks are shown in **Table 10**.

Table 10 Sugarcane feedstocks characteristics affecting logistics for biofuels production.

FEEDSTOCK CHARACTERISTICS	SUGARCANE STALK	SUGARCANE BAGASSE	SUGARCANE LEAVES
Plant part	Stalk, either whole stick from burned cane or billets from green cane harvesting	Wet bagasse from crushing cane stalks	Dry and green leaves from green cane harvesting
Present feedstock logistics	Transport harvested cane stalks to the mill (up to 50 km; avg 30 km)	Produced at the mill, no transportation required if conversion technology is located at the mill	It can be transported to the mill mixed with stalks or baled (up to 50 km; avg 30 km)
Relative importance of feedstock logistics in final biofuels cost	High (~20-50 % of ethanol)	Tend to be high because bagasse tends to be priced as cane. But bagasse is available at the mill	Tend to be high because leaves tend to be priced as cane. Low density material. If collected separately from stems, extra logistics costs apply
Average Yield	60-100 tons of cane stalks/ha.year	20-25 tons of wet bagasse/ha.year	20-25 tons of green leaves/ha.year
Feedstock bulk density	Low (~200 kg/m^3)	Low (~200 kg/m^3)	Low (~200 kg/m^3)
Feedstock Moisture Content	High (~70% d.b.)	High (~50% d.b.)	High (~50% d.b.)
Harvest Season	April-November in Central South Brazil	April-November in Central South Brazil	April-November in Central South Brazil
Need to be processed after harvest	Needs to be processed with 24-48h after harvest	No need to be processed immediately	No need to be processed immediately
Storability	Difficult. Eventually sucrose can be concentrated and fiber can be densified	Can be stored as is (bagasse is normally stored) or densified as bales or pellets	Can be stored as is or densified as bales or pellets
Importance in Brazilian Food (Domestic and Exports)	High	No use for food	No use for food
Importance in Brazilian Energy Matrix	High (ethanol accounts for ~10%)	High (bagasse accounts for ~10%)	Limited use for energy at present
Total annual production	650 million tons of stalks (sucrose + bagasse + water)	250 million tons of wet bagasse	250 million tons of wet leaves

For a better understanding of how sugarcane is produced in Brazil a typical sugarcane mill may be taken as an example (CGEE, 2012):

1. Production capacity: 2 million tons/year (operating 200 days/year);
2. Harvest 25,000 ha/year; Needs to reform (plant): 4,000 ha/year;
3. Annual production: 160 million liters ethanol, 500,000 t bagasse; 1.5 billion liters of vinasse; 70 million tons of filter cake; 250 thousand tons of straw;
4. Transportation system by truck (traylers or semi traylers):
    (a) By "*rodotrem*[5]" (60 tons of payload): mill receives avg 7 rodotrens/h;
    (b) By "*treminhão*[6]" (45 tons of payload): mill receives avg 9 rodotrens/h.

Using a harvester with a 600 tons/day (25 tons/h), 16 harvesters and other 30 tractors and 60 infield wagons are needed. Considering average transportation distance around 40 km, 28 transportation units ("*rodotrens*") are needed for the typical sugarcane mill.

Three field operations – cutting, loading, and transporting, represent in average, 34 to 39% of the sugarcane cost in Brazil (**Table 11**). Therefore it becomes essential to optimize on-farm logistics as well.

Table 11 Sugarcane Production Cost in Brazil (Central South Region, Harvest 2011/2012) (PECEGE, 2012).

	Cutting-Loading-Transportation Cost (CLT)		Mechanization Cost (MC)			Production Cost (PC)
	R$/t	% PC	R$/t	% CLT	% PC	R$/t
Producers (traditional)	23.92	33.9%	17.32	72.4%	24.5%	70.63
Producers (expansion)	20.46	36.3%	19.04	93.1%	33.8%	56.29
Mills (traditional)	23.56	33.6%	15.03	63.8%	21.5%	70.06
Mills (expansion)	23.56	38.9%	15.38	65.3%	25.4%	60.52

Notes:
- Machines and equipment depreciations are included in Mechanization Cost.
- CLT: included Mechanization Cost, Manpower and Inputs.
- Mechanization cost: Costs of Cutting, Loading and Transportation of sugarcane (only machines and fuel).

Sugarcane in Brazil yields sugar and ethanol. Both can be used as feedstock for the production of biofuels for aviation. The present location of existing plants (black dots) and planned units (yellow dots) are shown in **Figure 31**. From these plants both products are typically transported by trucks to sugar refining centers (some sugarcane mills also refine sugar) or fuel terminals, or exported, depending on the case. Ethanol pipelines will so be

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[5] *Rodotrem*: combination of a semi trailer-truck and a large semi-trailer.

[6] *Treminhão*: combination of a single trailer-truck and two semi-trailers.

available. A 215-km ethanol pipeline linking Ribeirão Preto, in the main producing region, to Paulinia, the largest petroleum refining and distribution hub in Brazil, is about to be inaugurated (O ESTADO DE S. PAULO, 2013). An addition, another 136 km stretch of this pipeline, from Ribeirão Preto to Uberaba will probably be ready early in 2014 that will allow the transport of ethanol from areas of the new sugarcane frontier.

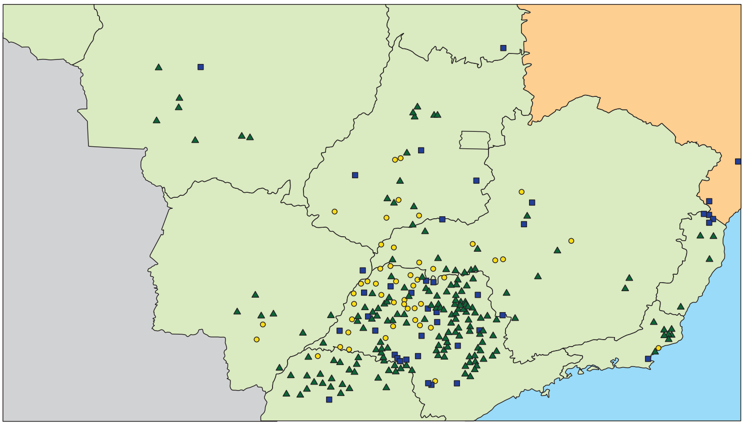


Figure 31 Present location of sugar-ethanol mills. Source: CGEE, 2009.

CGEE (2009) discussed the possibilities of Brazil to produce enough sugarcane ethanol to substitute 10% of 2025 consumption of gasoline worldwide. The necessary amount is around 205.5 billion liters of ethanol. Seventeen areas were selected in Brazil and the logistics associated with ethanol transportation were considered. **Figure 32** illustrates the necessary transportation schemes. The CGEE (2009) report is a fine example of the potential of sugarcane to supply large quantities of biofuel not only for the Brazilian market, but also for export.

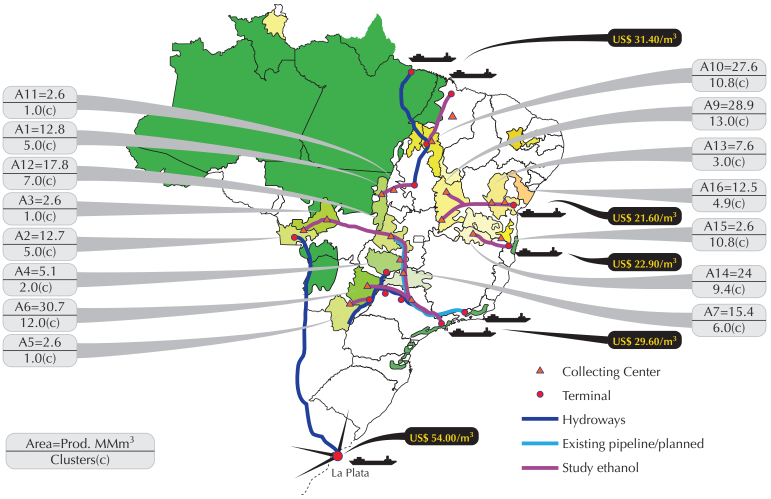


Figure 32 Possible ethanol transportation routes for Brazil to supply ethanol to replace 10% of the world gasoline consumption by 2025. Source: CGEE, 2009.

Wood

The present situation of forests in Brazil indicate that public forests are mainly in the Amazon region or scattered small portions over the whole territory and the forest plantations more concentrated in the State of Minas Gerais and São Paulo, as shown in **Figure 33**. Natural forests are not suitable feedstock for jet biofuel because of the restriction due to sustainability questions.

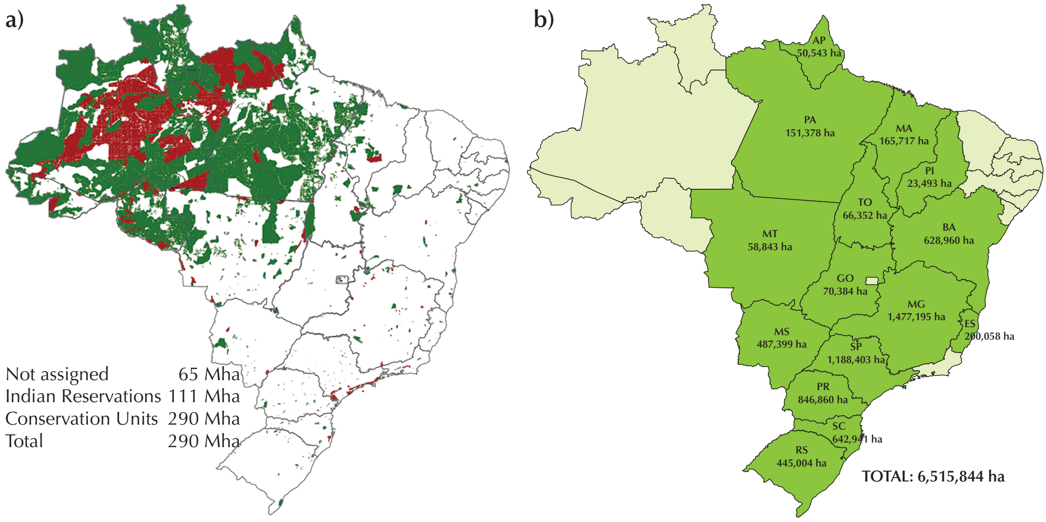


Figure 33 (a) Public Forests in Brazil. Source: SFR apud Rodriguez. (b) Forest Plantations in Brazil. Source: ABRAF apud Rodriguez, 2012.

Forest plantations all together covered nearly 6.5 million ha in 2011 (ABRAF, 2012), coincidentally approximately the same as sugarcane area with a very good potential to grow since its productivity in Brazil is higher than observed in other regions (see **Figure 33** and **Table 12**). According to ABRAF (2012) total wood production in 2012 in Brazil was estimated in 255 million m^3 (77% eucalyptus and 23% pines).

Table 12 Planted forest productivity in selected countries (NAHUZ, 2012).

COUNTRY	SPECIES	GROWTH RATES (m^3/ha/year)	ROTATION (year)
Brazil	Eucalyptus	35 – 50	6
	Pine	20 – 35	12 – 20
Chile	Eucalyptus	25 – 30	8 – 12
	Pine	20 – 30	25 – 30
Argentina	Eucalyptus	15 – 30	10 – 14
	Pine	20 – 25	20 – 25

Table 12 Planted forest productivity in selected countries (NAHUZ, 2012).

COUNTRY	SPECIES	GROWTH RATES (m^3/ha/year)	ROTATION (year)
Uruguay	Eucalyptus	20 – 35	8 – 12
	Pine	20 – 25	20 – 25
Venezuela	Pine	8 – 20	15 – 20
China	Eucalyptus	9 – 18	5 – 10
	Fir	10 – 14	18 – 20
Indonesia	Acacia	20 – 25	6 – 7
Thailand	Eucalyptus	12 – 25	6 – 7
Malaysia	Acacia	15 – 25	7 – 9
Australia	Eucalyptus	15 – 25	10 – 12
	Pine	15 – 25	25 – 35
New Zealand	Pine	15 – 30	25 – 35
Spain	Eucalyptus	10 – 21	8 – 20
	Pine	4 – 15	25 – 40
Portugal	Eucalyptus	10 – 18	8 – 10
UK	Spruce	12 – 14	40 – 60
Ireland	Spruce	15 – 18	40 – 45
South Africa	Eucalyptus	20 – 22	6 – 10

One hectare of eucalyptus, managed to produce 45 m^3/ha.year over 7 years rotations using mechanized harvesting for pulp wood (harvesters/feller bunchers) or (chainsaw/ forwarders) and debarking on site, is expected to provide, according to an estimate of total forest products of 1 ha of eucalyptus was made by Nahuz (2012), based on Foelkel (2007), using the following conditions: Eucalyptus sp.; productivity of 45m^3/ha.year; cutting cycle – 7 years; using mechanized harvesting for pulping (harvesters/feller bunchers) or (chainsaw/ forwarders); debarking on site. Total harvested volume: an average of 315 m^3/ha. The resulting residues are: (thick branches (> 2 cm): 3.05 m^3/ha; tops (diameter < 7 cm): 8.70 m^3/ha; thin trees (left standing): 4.70 m^3/ha; logs (leftover): 1.6 m^3/ha; bark: 3.9 m^3/ha; stump (7.5 cm): 0.63 m^3/ha; total residues: amounting to 21.96 m^3/ha (7%) and a net volume for pulp of: 293.04 m^3/ha (93%).

Logistics (transportation) plays an important role in wood overall costs. Data of **Table 13** indicated that Harvesting & Transport combined with Road represented more than 25% of the investment in 2011 by the sector.

Table 13 Participation & prospective investment on wood production (2011 & 2012-2016) (ABRAF, 2012).

ITEM	PARTICIPATION 2011		PROSPECTIVE 2012-2016	
	million R$	(%)	million R$	(%)
Planting	1,041	35.9	3,442	43.7
Harvesting & Transport	629	21.7	2,038	25.9
Land	589	20.3	343	4.4
Industry	4	13.8	976	12.4
Roads	116	4.0	469	5.9
R&D	35	1.2	409	5.2
Other	9	3.1	202	2.6
Total	2,900	100.0	7,879	100.0

Wood harvesting is an expensive logistics element in wood overall costs. The technology employed depends on the distance:

Figure 34 presents the distribution of forest plantations and industrial wood consumers in Brazil.

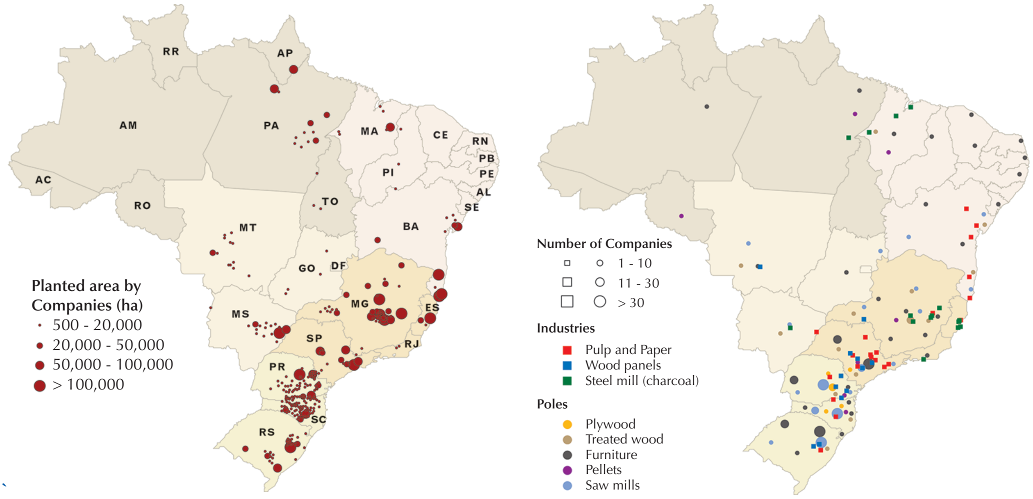


Figure 34 (a) Distribution and size of forest plantations. (b) Distribution of industrial wood consumers. Source: ABRAF apud Rodriguez, 2012.

According to BRACELPA (2009) the average distance from the forest to the factory is about 88 km. Transportation represents 30-60% of the harvest+transportation costs, basically transported by truck (96% of total). However wood can also be transported by train or ships in Brazil, although the existing infrastructure is limited.

For urban residues, the cost of separation of useful material will comprise the highest component of overall cost because the residues are already close to industry or places with infrastructure to process the feedstock into jet fuel.

4.2 Refining Technologies

Aviation kerosene, from fossil source has been used on commercial aviation for over 50 years. It is a well-known product (jet A/A1 turbine fuel), meets international specifications (Joint Operated System, ASTM, DefStan, Military Standards, etc.) and is a complex combination of hydrocarbons between C8 and C16 and additives, separated by fractional distillation followed by treatments that warranty the product final qualities. Aviation kerosene is going to be used on commercial aviation for many years, since it satisfies the fleet and existing infrastructure technical requirements (BLAKEY et al., 2010). The composition and properties of a desirable jet biofuel should be similar to petroleum jet fuel. **The term "drop-in fuel" is used to describe an alternative fuel, that is indistinguishable from conventional fuel, with no changes of aircraft, engine or supply infrastructure required, according to IATA**. The international requirements issued by ASTM D4054 (Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives), D1655 (Specification for Aviation Turbine Fuels), D7566 (Aviation Turbine Fuel Containing Synthesized Hydrocarbons), and UK-MoD Defense Standard 91-91, make sure that the fuels properties are fully assured, in order to ensure the proper performance of the aviation fleet.

Petrochemical refining processing has evolved during the last 100 years in hundreds of refineries over the world. The worldwide consumption by aviation is approximately 200 million tons of kerosene per year. European consumption in 2010 was 53 million tons from petrochemical conversion processes, which is extremely complex but very efficient on such a massive scale. Aviation is one of the fastest growing transport sectors, and up to 2050, worldwide aviation is expected to grow by 4.5% annually (GOODWIN; LYONS, 2010).

Sustainable jet fuels are produced from various feedstocks by a combination of different operations of 1) pretreatments, 2) conversion and 3) technological process to obtain the jet fuel.

The approach which is going to be used in this text is that some pretreatments are not going to be detailed separately from the most important conversion technologies associated to refining processes developed so far to lead to renewable fuels. Combinations of those will be needed to lead to the best technologies to produce renewable drop-in jet biofuel. It is important to realize that each process used to transform different types of biomass to jet fuel containing synthesized hydrocarbons has specific efficiency and yield. Thus, combining different operations will result in different conversion ratios and yields. Therefore, in order to compare different processes, for a given biomass to a desired product, the yield, productivity, selectivity and properties of each operation should be taken into account.

The desirable product of this project is a jet biofuel. However, this fuel must be price competitive and a "drop-in" jet fuel.

General Analysis of Components

Diverse other biofuels have applied to be certified as jet fuel (CHARLES et al., 2007), although this will depend on the advances of the technologies by the producing industries. They are produced from renewable biomass, by a combination of different operations:

1. pretreatments of the biomass (steam explosion, hydrolysis of lignocellulose, pyrolysis, etc);
2. conversion (fermentation to alcohols, farnesene, lipids and other building blocks), gasification, fast pyrolysis or solvent liquefaction, direct conversion of sugars to fuels by catalyzed reactions) and;
3. technological processes to obtain the jet fuel, as Fischer-Tropsch synthesis, HEFA processing, upgrading by catalytic hydrogenation, alcohol oligomerization, etc.

Most of the new technologies, such as fermentation of sugars to alcohols of different chain lengths, catalytic conversion of alcohols to hydrocarbon fuels, biological production of lipids, alcohols, organic acids or other building blocks by fermentation by microalgae, bacteria, and yeasts, further transformed in jet fuels, are technically feasible and are still being scaled up and validated (DIAS, 2011).

Biomass as source for biofuels

Among the several feedstocks already mentioned, which included wastes and industrial residues not necessarily from recent bio-origin, biomass deserves special considerations.

In order to partially replace petrol fuels by biofuels, our focus should be also on reducing overall cost by converting biomass into refinery ready materials that use today's infrastructure and distribution channels. This partial replacement seem to offer high potential in Brazil, due to the local abundance of large national areas originated from degraded pasture or not-in-use land (LUQUE et al., 2012; LEITE et al., 2009).

Abundant biomass is considered a low to medium concentration energy source, easily obtained via photosynthesis.

The main constituents of biomass are polysaccharides (hemicellulose, cellulose, starch, etc.), monosaccharides, lignin, oils and fats and proteins, which offer potential energy applications. They may be derived from anything from forest-harvested material to significantly diverse products (quantitatively and qualitatively), depending on the species/techniques used. They can also be originated from plant harvesting or wood processing, achieving a high local concentration index and considerably heterogeneous products, or even from cultures of short and medium rotation with a potential for energy use. Often they are originated from urban municipal wastes, as also from animal, vegetable and industrial and forest residues. Lipids have different chemical formulas, as triacyl glycerides, esters, fats and oils, and other hydrophobic (low polar) compounds (CASTOR et al., 2003).

The feedstock is a critical element in the production of a biofuel for aviation. (KOIZUMI, 2013). It needs to be rich energy dense molecules, as sugars, starch, fat, oil or lignocellulose, obtained directly or indirectly by cultivating crops, from wastes, residues or microbial biomass (microalgae, yeasts, etc.). Therefore, 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 (JENKINS et al., 2013).

4.3 Logistics

4.3.1 Actual jet fuel distribution logistics and infrastructure

The jet fuel logistics everywhere was constructed for supplying the fossil fuel to the airports. Therefore, any alternative fuel has to make the best possible use of the available infrastructure to become more competitive. **Figure 35** locates the Brazilian Refineries, pinpointing the ones that produce jet fuel by the amount produced during the year of 2011. The main source of data for this whole section is ANP – National Agency for Petroleum, Natural Gas and Biofuels (see "Anuário Estatístico 2012" at ANP website). The refining capacity concentration in the Southeast region surpasses 80%. It is worth recalling that Brazil has imported 25% of the jet fuel consumption in 2011, fact that allows the substitution of internal distribution by long distance cabotage, by jet fuel importation. The main ports for this matter are São Sebastião in São Paulo State, Suape in Pernambuco and São Luiz in Maranhão, as indicated in the figure. REVAP, the refinery at São José dos Campos, is the largest jet fuel producer in the country, and its entire production is completely used in supplying the "fuel farm" at Guarulhos International Airport (IATA code: GRU).

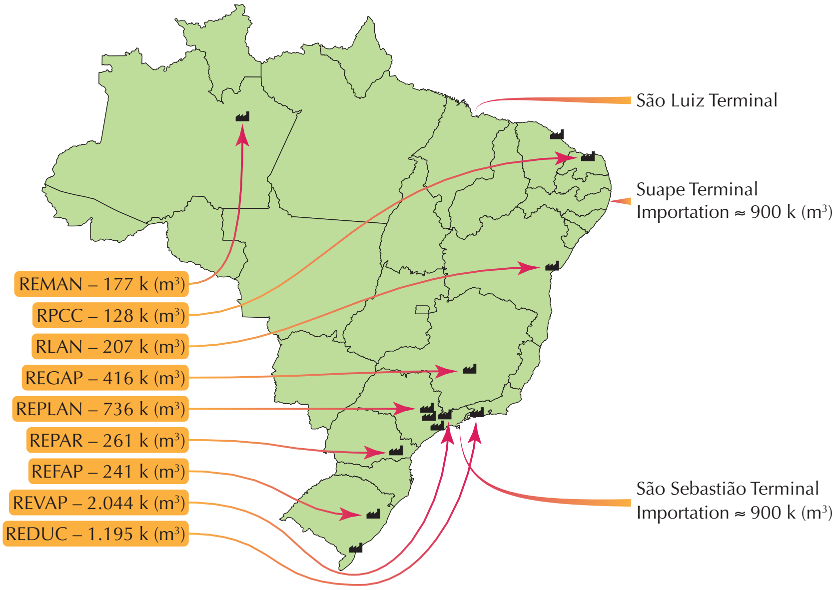


Figure 35 Oil Refineries and Jet Fuel Supply for the Year of 2011.

Figure 36 displays the location of the 149 airports that have to receive jet fuel regularly in the country. It is important to remark that circa one third of them, mainly in the Amazon region, can only be reached by air or by waterways commonly not navigable all year around. This fact can complicate the jet fuel distribution logistics in those areas, where it is not unusual for the jet fuel to be stored for more than six months. Although the jet fuel consumption under those conditions is estimated here to be less than 3% of the total, it cannot be ignored when one are thinking of implementing the use of renewable drop-in jet fuel. Another aspect worthwhile to pinpoint is that only the airports of Guarulhos and Galeão (IATA code: GIG) are supplied by pipelines, while the remaining are supplied by tank trucks or, eventually by barges.

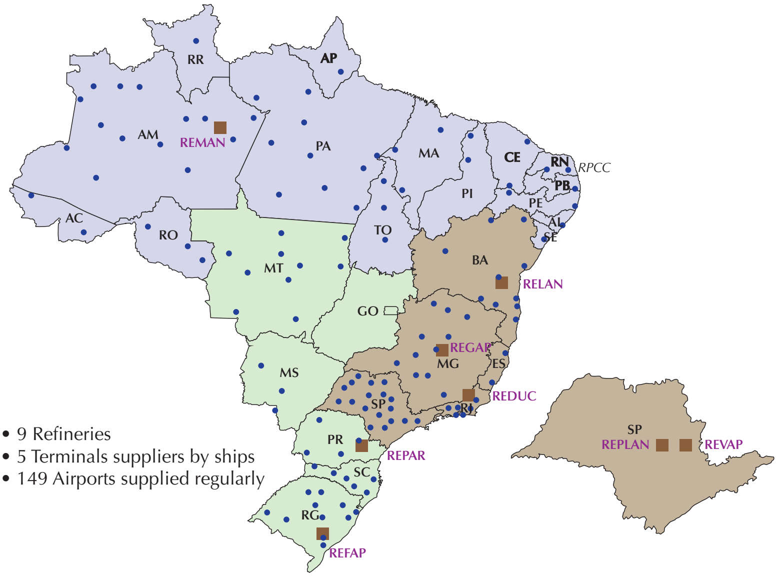


Figure 36 Location of Airports Supplied by Jet Fuel Regularly. Source: Sindicom apud Schumman, 2012.

Figure 37, presented by SINDICOM in 6th workshop, gives an overall picture of jet fuel logistics in Brazil.

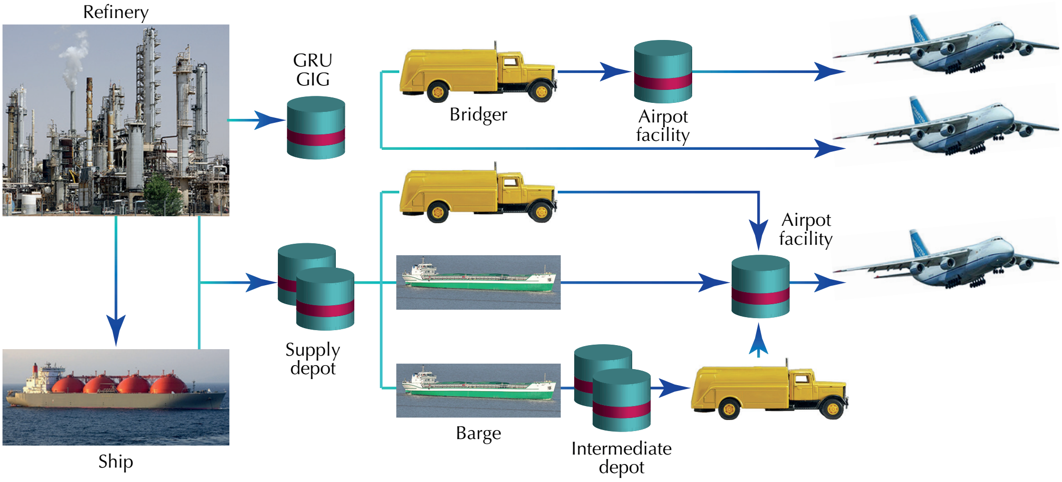


Figure 37 General View of Jet Fuel Distribution Logistics in Brazil. Source: adapted from Sindicom apud Schumman, 2012.

Figure 38 presents the municipal areas were the main airports in terms of demand for jet fuel are located, together with an estimation of their daily consumption. The metropolitan regions of São Paulo and Rio de Janeiro, followed by Brasilia, are the most important.

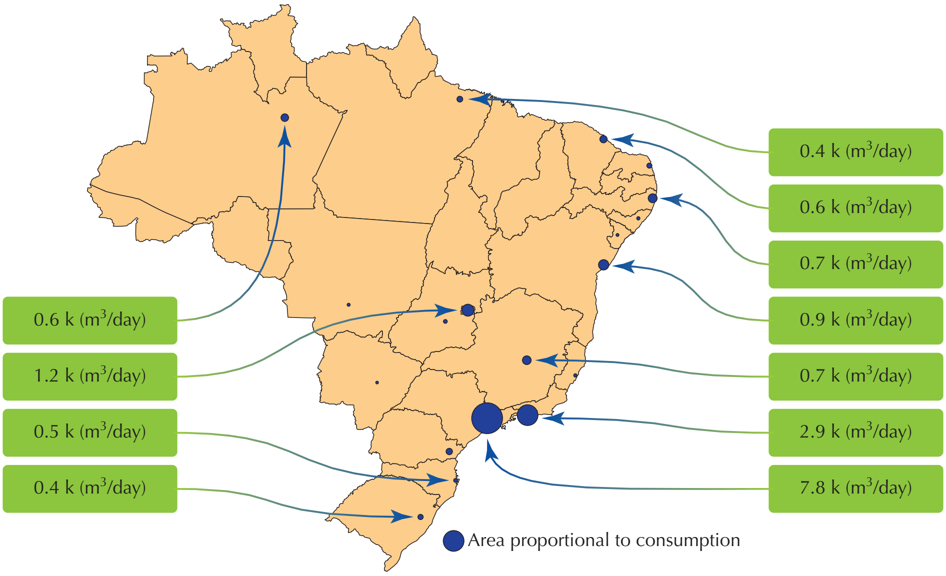


Figure 38 Main Consumption Sites.

The States of São Paulo and Rio de Janeiro consumed 4 million m^3 in 2011, corresponding to 56% of the country's consumption, of which 45% was due only to Guarulhos and Galeão international airports. Each region of the country has its particular distribution logistics by tank trucks or barges as detailed by SINDICOM during 6th workshop and the whole supply is provided by Petrobras.

Figure 39 presents schematically the supply logistics for the largest consumer, Guarulhos International Airport. It is worthwhile to observe that the supply of Congonhas Airport is made by tank trucks loaded in the same Guarulhos Fuel Farm that supplies the International Airport. Similarly, although not indicated in the figure, several small airports in Sao Paulo State are supplied by tank trucks loaded in the same Fuel Farm.

According to Petrobras presentation at the same workshop, the supply situation of each regional Brazilian jet fuel market can be described by:

1. **North Region** (comprising mainly REMAN Refinery and Belém Terminal): area is under-stocked; an increase in production is difficult; the source to complement demand is the use of ships to bring jet fuel from other regions;
2. **Northeast Region** (comprising mainly the terminals in São Luiz, Fortaleza and Suape and the refineries RELAM and RPCC): area is under-stocked, except for Rio Grande do Norte due to RPCC production; both refineries have capacity to increase production; the source of complementary volume is the use of ships bringing imported jet fuel to Suape and São Luiz Terminals; part of the imported volume is used to supply other markets;

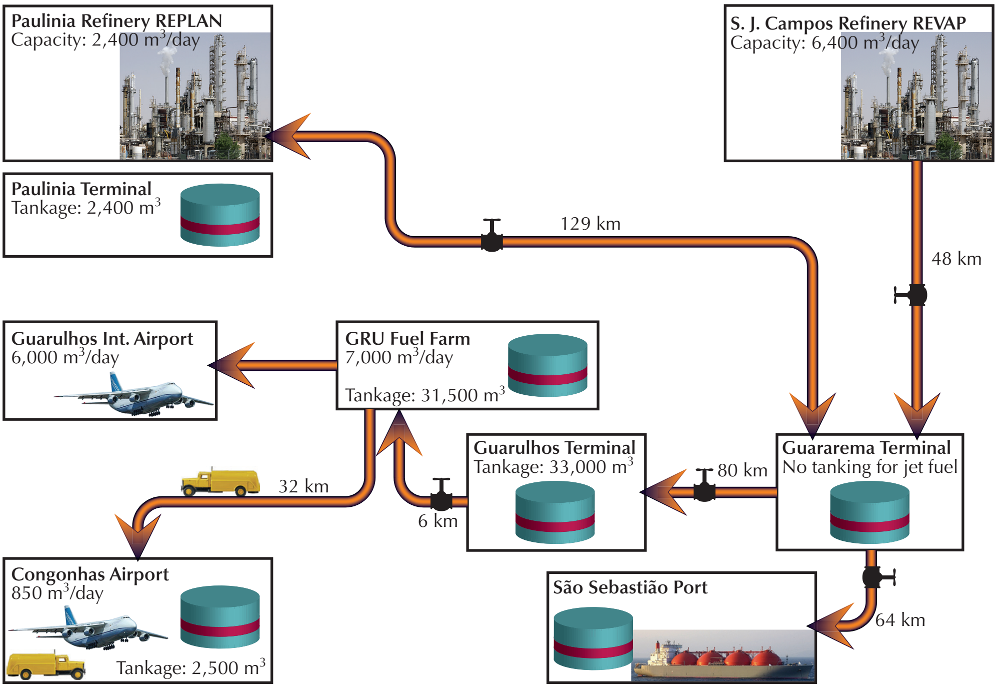


Figure 39 Pipeline Infrastructure for Supplying Guarulhos and Congonhas Airports. Source: Sindicom apud Schumman, 2012.

3. **Southeast/Midwest Region** (comprising REVAP, REDUC, REPLAN and REGAP refineries and São Sebastião Terminal): REGAP (Minas Gerais) is balanced while São Paulo System and REDUC (Rio de Janeiro) are under-stocked; there are few possibilities of production increase on these areas; the source of complementary volume is the use of ships arriving at São Sebastião Terminal, which accounts for 50% of all the imported jet fuel by the country; part of the imported volume is used to supply other markets;
4. **South Region** (comprising REPAR and REFAP refineries): both systems are balanced and it is possible to increase their productions.

Summarizing the jet fuel logistics in Brazil, one can say that the country has a single producer and importer, Petrobras, four authorized distributors, 13 supply sites (9 refineries and 5 water terminals and 173 authorized resellers. The consumption is extremely concentrated mainly in the Southeast Region of the country and almost each large airport has as a nearby supplier that is a refinery or a maritime terminal. The exception here is the Brasilia International Airport, which is supplied from REGAP by tank trucks through a distance of 700 km. On the other hand, the country has many small airports in remote regions, mainly in the North Region, that can be reached only by air or waterways during part of the year, forcing the jet fuel to be stored for longer than normal periods.

4.3.2 Quality assurance procedures for jet fuel

a. Conventional jet fuel

In order to ensure flight safety, jet fuel is submitted to very strict quality requirements that tag along its whole production and distribution chain up to the airplanes fuel tanks.

These fuel requirements, which are used by the Civil Airworthiness Authorities (ANAC in the Brazilian case) to ensure the safety of aircraft operations, are very similar all over the globe to allow for interoperability, for instance, of international flights. They are based essentially on fuel specifications and quality assurance procedures along the fuel distribution chain.

On the side of the airplanes, airworthiness regulations issued for aircraft and engines require that operating limitations be established for each certificated design based on the specified fuel.

In Brazil, ANP regulates the distribution and re-sale of jet fuel through Resolutions (in Portuguese) Nr. 17/2006 – "Regulates the activities of distribution of aviation fuels" and Nr.18/2006 – "Regulates the activities of re-sale of aviation fuels", and establishes the specifications of jet fuel through Resolution (in Portuguese) Nr. 37/2009, which refers to the Brazilian Standards (in Portuguese) ABNT NBR 15216 "Storage of flammable and combustible liquids – Quality control on storage, transportation and supply of aviation fuels"

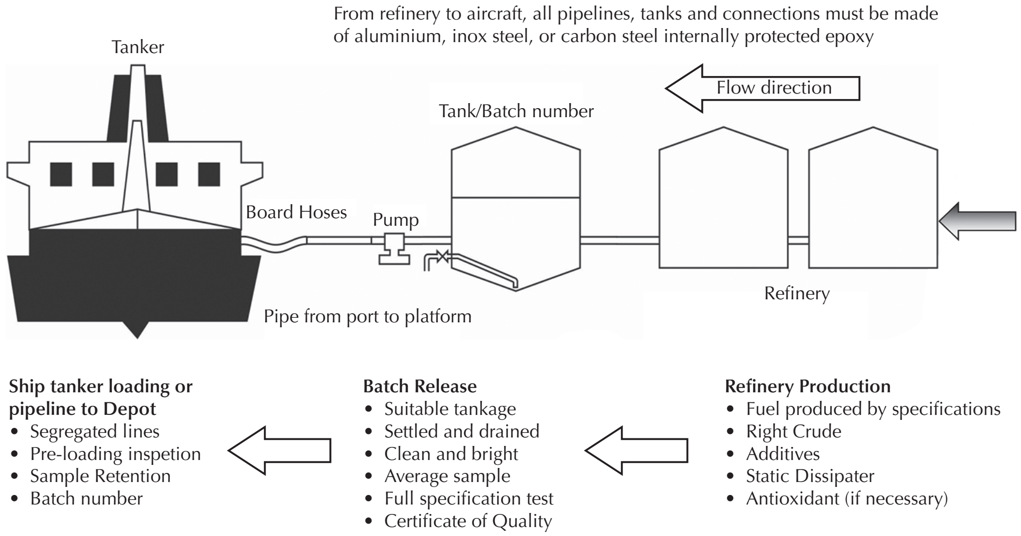
In essence the jet fuel specification follows ASTM D1655 – "Standard Specification for Aviation Turbine Fuels" and Defence Standard 91-91(UK) [10].

Quality assurance, similarly, is based on the concepts of "batches" and "traceability". A batch of fuel is defined as a distinct quantity of jet fuel that can be characterized by one set of test results. It is essential that producers ensure batches are homogenous so that test results are representative of the product supplied. In case of petroleum derived jet kerosene, these batches have to be certified at the origin according to ASTM D1655, DS 91-91 or, in Brazil, ANP Resolution Nr. 37/2009.

As presented in the workshop by SINDICOM, **Figure 40**, **Figure 41**, **Figure 42** and **Figure 43** illustrate the main quality control procedures from the refinery, through the distributors and up to the airplane fuel tanks.

b. Alternative jet fuel

Present specification (ASTM D1655 or DS 91-91) evolved as performance specification rather than compositional specification. They rely on accumulated experience and therefore, if the fuel does not originate from conventional sources or specifically approved synthetic processes, it is not enough for the fuel to meet the specification in order to be fit for use as aircraft turbine fuel. One should observe that any significant change on performance in terms of materials compatibility or engine testing would imply in recertification of all existing aircraft. For this reason, any alternative jet fuel has to be shown, not to have the same chemical composition of the petroleum derived jet fuel, but to be fit-for-purpose of being used without difference as a traditional jet fuel.

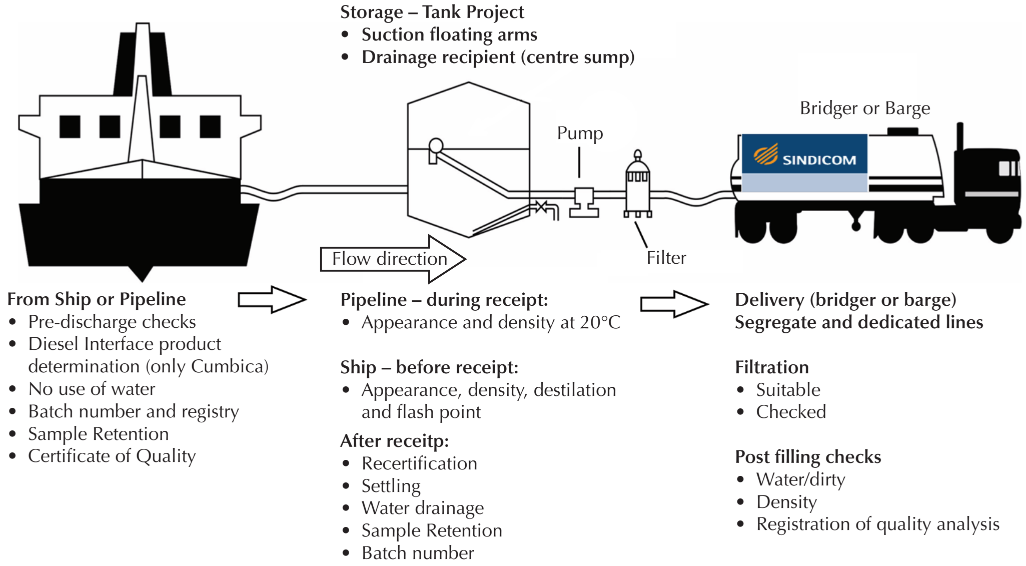


Ship tanker loading or pipeline to Depot
- Segregated lines
- Pre-loading inspetion
- Sample Retention
- Batch number

Batch Release
- Suitable tankage
- Settled and drained
- Clean and bright
- Average sample
- Full specification test
- Certificate of Quality

Refinery Production
- Fuel produced by specifications
- Right Crude
- Additives
- Static Dissipater
- Antioxidant (if necessary)

Figure 40 Quality Control Procedures from Refinery to Tanker or Depot. Source: Sindicom apud Schumman, 2012.



Storage – Tank Project
- **Suction floating arms**
- **Drainage recipient (centre sump)**

From Ship or Pipeline
- Pre-discharge checks
- Diesel Interface product determination (only Cumbica)
- No use of water
- Batch number and registry
- Sample Retention
- Certificate of Quality

Pipeline – during receipt:
- Appearance and density at 20°C

Ship – before receipt:
- Appearance, density, destilation and flash point

After receitp:
- Recertification
- Settling
- Water drainage
- Sample Retention
- Batch number

Delivery (bridger or barge) Segregate and dedicated lines

Filtration
- Suitable
- Checked

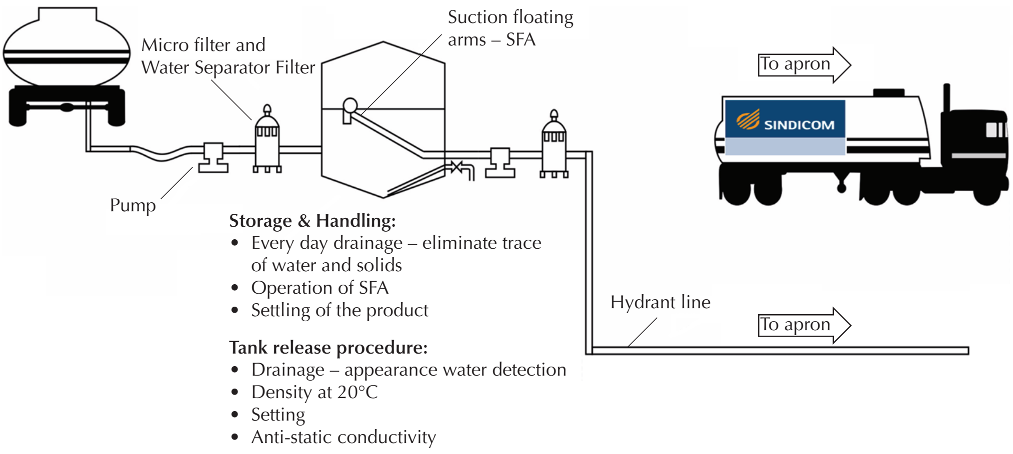
Post filling checks
- Water/dirty
- Density
- Registration of quality analysis

Figure 41 Quality Control Procedures from Tanker or Pipeline to Depot. Source: Sindicom apud Schumman, 2012.

Bridger and Barge discharge:
Certificate of Analysis
Drainage
- Water
- Solids
- Density at 20°C

To release the product to the gantry loading or to the hydrant system is necessary to assure quality control by checking density at 20°C, appearance (water and solids) and measurement of anti-static additive.

Obs.: The product contained in a depot or airport tanks must be recertificated if there is no product receiving in a period of 6 month.



Storage & Handling:
- Every day drainage – eliminate trace of water and solids
- Operation of SFA
- Settling of the product

Tank release procedure:
- Drainage – appearance water detection
- Density at 20°C
- Setting
- Anti-static conductivity

Figure 42 Quality Control Procedures at Airport Facilities.
Source: Sindicom apud Schumman, 2012.

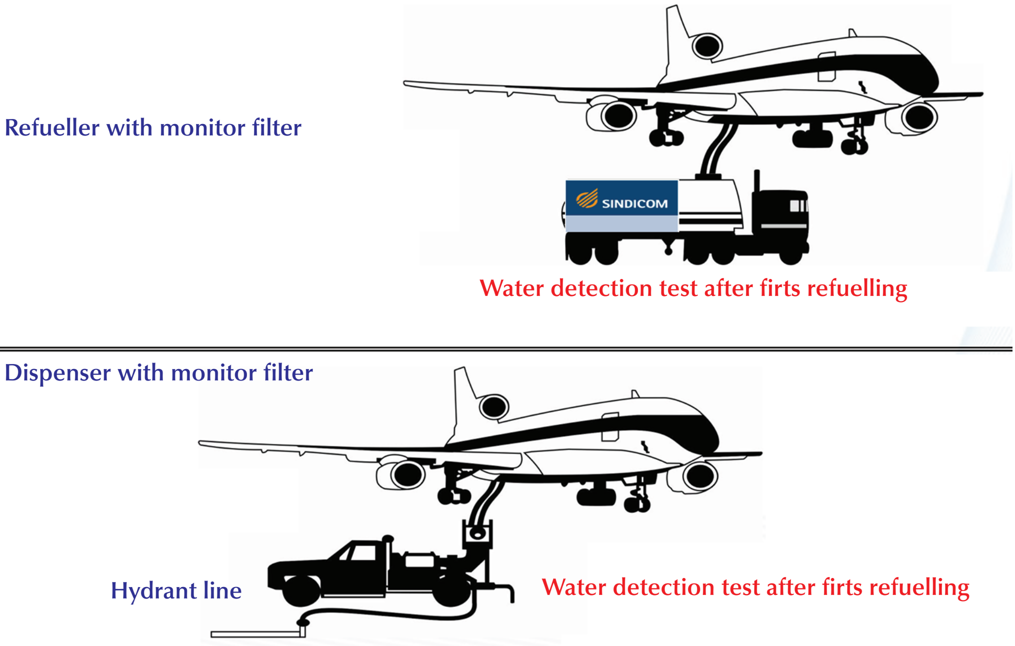


Figure 43 Quality Control Procedures at Apron.
Source: Sindicom apud Schumman, 2012.

Besides satisfying the standards above mentioned, the alternative fuels have to meet the terms of ASTM D4054 - “Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives” and ASTM D7566 - “Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons”.

In this case, the alternative fuel would be a “drop-in” fuel, with features described in ASTM D7566 – as: “*Because the drop-in alternative fuel will be incorporated into the existing jet fuel specifications, there will be no change required to these operating limitations and no associated certification testing. In effect, the alternative fuel seamlessly enters the fuel distribution infrastructure and requires no special treatment or identification, and is co-mingled with conventional jet fuel. From the perspective of the certificated aircraft and engine, conventional fuel and the drop-in alternative fuel provide identical performance and safety*”.

The guidelines for qualification and approval of New Aviation Turbine Fuels and Fuel Additives according to ASTM D4054 are presented schematically in **Figure 44**. As one can observe, after a very extensive test program, the results are submitted to an internal review by the OEMs to reach the stage of possible specification change, for instance to include a new annex to ASTM D7566.

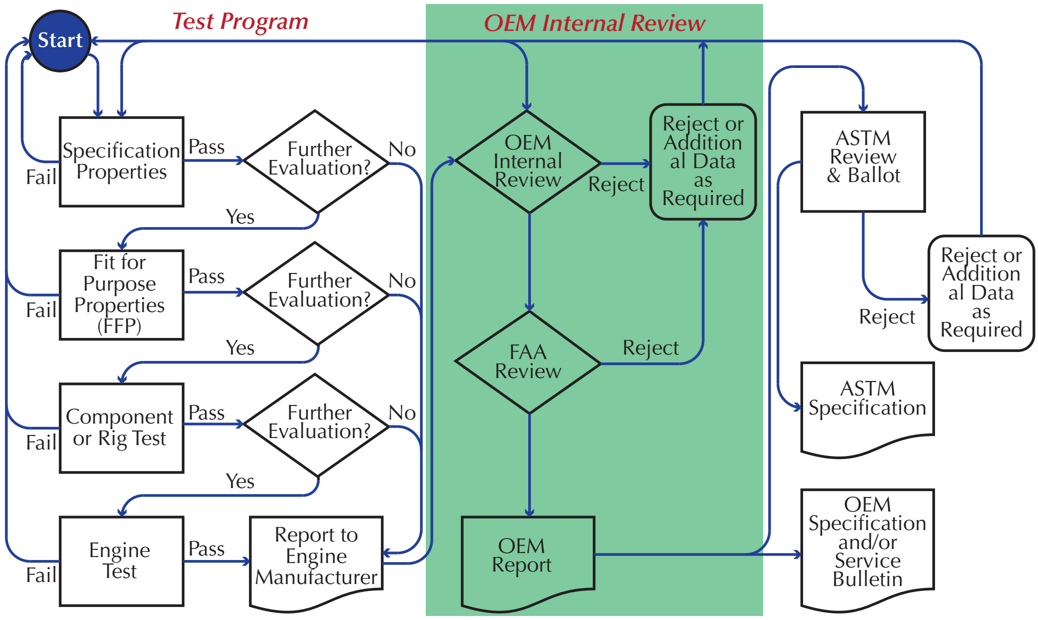


Figure 44 Guideline for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives According to ASTM D4054.

Table 14, reproduced from presentation by George Wilson III, lists the types of testing required for a jet fuel, from a different source than petroleum, to pass the test program.

Table 14 Test Program Requirements for Alternative Fuels for Aviation.

SPECIFICATIONS	FIT FOR PURPOSE	MATERIAL COMPATIBILITY	ENGINE ENDURANCE TEST
Composition	**Chemistry**	**Additive Compatibility**	**Hot Section Corrosion/Erosion**
Acidity	Hydrocarbon Type	FSII	Metallurgy
Aromatics	Aromatics	CI/LI	Coating
Sulfur	**Trace Materials**	SDA	**Component Testing**
Volatility	Organics	AO	Fuel System
Distillation	Inorganics	MDA	Fuel Pump
Flash Point	Metals	**Fuel to Fuel Compatibility**	Fuel Control
Density	**Bulk Property**	**Non Metallic Materials (37)**	Fuel Nozzle
Fluidity	Precision Distillation	Adhesives	Combustor Rig Testing
Freeze Point	VapP vs T	Bladders	Cold Start, SL to 10,000 ft
Viscosity	Deposition Characteristics	Aircraft Coatings	Lean Blowout
Combustion	Lubricity/CI Response	Bulk Tank Coatings	Aerial Restart
Heat of Combustion	Vis vs T	Sealants	TIT Distribution
Smoke Point	Spec Heat vs T	Composite Materials	Combustor Efficiency
Corrosion	Density vs T	Foams	Carboning/Coking
Thermal Stability	Surf Ten vs T	O-rings	Emissions
Contaminates	Bulk Modulus vs T & P	Nitrile	APU Altitude Start
Existent Gum	T Cond vs T	Fluorosilicone	**Engine Test**
MSEP	Water Sol vs T	Fluorocarbon	
Additives	Flash Point	Gaskets	
Conductivity	Freeze Point	Fuel Hose	
	Electrical Properties	Teflon	
	Dielectric vs Density	Nylon	
	Conductivity/SDA Response	Polyethylene	
	Handling and Safety	Kapton	
	Effect on Clay	Potting Compound	
	Filter Separator Efficacy	**Metals/Metal Coatings (31)**	
	Monitor Performance	Al·Cr Anodize	
	Storage Stability	Sulfuric Anodize	
	Peroxides over time	Chromate Conversion	
	Potential Gum	Wrought Aluminun	
	Toxicity	Cast Aluminum	
	LEL & UEL	CuNi	
	AIT	Solder	
	HSIT	Austentic Stainless Steel	
		Non-Aus SS	
		Titanium Alloys	
		IVD Coating	
		Fasteners	
		CPM	
		InCo	
		Nitralloy	
		Monel	
		Waspaloy	
		Lead	
		Brass	
		Wire	

The ASTM standard D7566 covers the manufacture of aviation turbine fuel that consists of conventional and synthetic blending components. Up to this time, the alternative fuels approved by ASTM shall consist of the following blends of components or fuels: conventional blending components or Jet A or Jet A-1 fuel certified to Specification D1655; with up to 50 % by volume of the synthetic blending component defined in Annex A1 or with up to 50% by volume of the synthetic blending component defined in Annex A2[7].

Annex A1 refers to a hydro-processed synthesized paraffinic kerosene wholly derived from synthesis gas via the Fischer-Tropsch process using Iron or Cobalt catalyst (FT- SPK). Subsequent processing of the product shall include hydro-treating, hydro-cracking, or hydro-isomerization and is expected to include, but not be limited to, a combination of other conventional refinery processes such as polymerization, isomerization, and fractionation.

Annex A2 refers to hydro-processed synthesized paraffinic kerosene wholly derived from hydrogenation and deoxygenation of fatty acid esters and free fatty acids (HEFA- SPK). Subsequent processing of the product shall include hydro-cracking, or hydro-isomerization, or isomerization or fractionation, or a combination thereof, and may include other conventional refinery processes.

Figure 45 and **Figure 46**, reproduced from a presentation by Lourdes Maurice from FAA, illustrate the already approved production processes according to ASTM jet fuel specifications and how the biofuel, after shown fit-for-purpose, becomes a drop-in jet fuel.

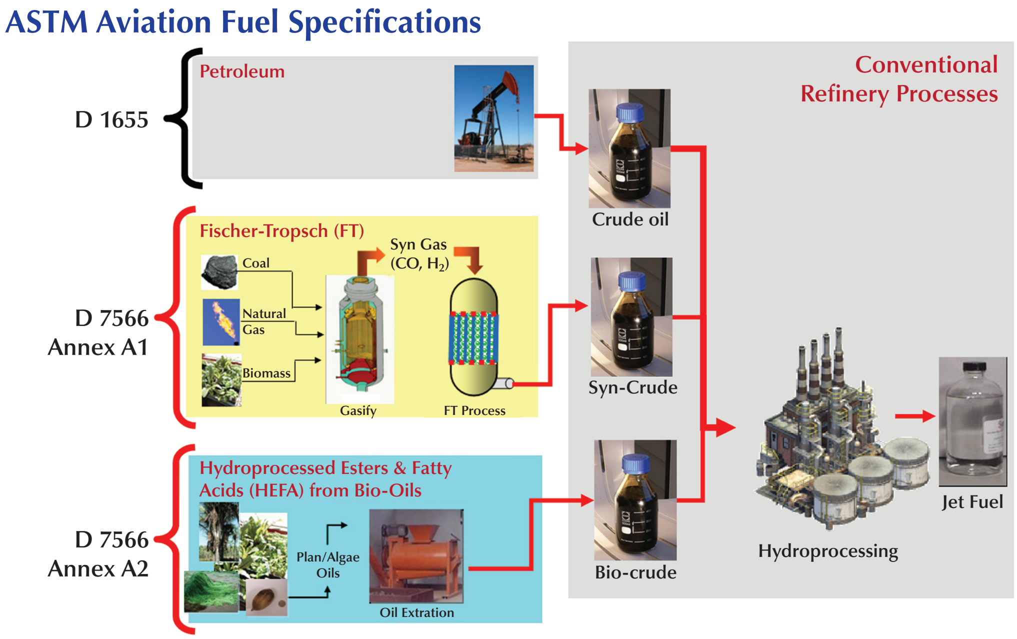


Figure 45 ASTM Approved Routes for Production of Jet Fuel.

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[7] Annex A3, which was introduced by ASTM in June/2014, refers to Synthesized Iso-Parraffins (SIP) produced from hydroprocessed fermented sugars that will be permitted for blending at up to 10% (vol) with conventional jet fuel. It is the approved denomination of the DSHC (direct sugar to hydrocarbon) route treated in this report as submitted to ASTM.

It is worth to remark that, as depicted in **Figure 46**, after approval by ASTM D7566 (inclusive blended according to the approved annexes) the certified batch is re-identified as satisfying ASTM D1655 and becomes fungible with any approved jet fuel from whichever origin, and can be used as an ASTM D1655 avoiding the whole process of re-certification of aircrafts.

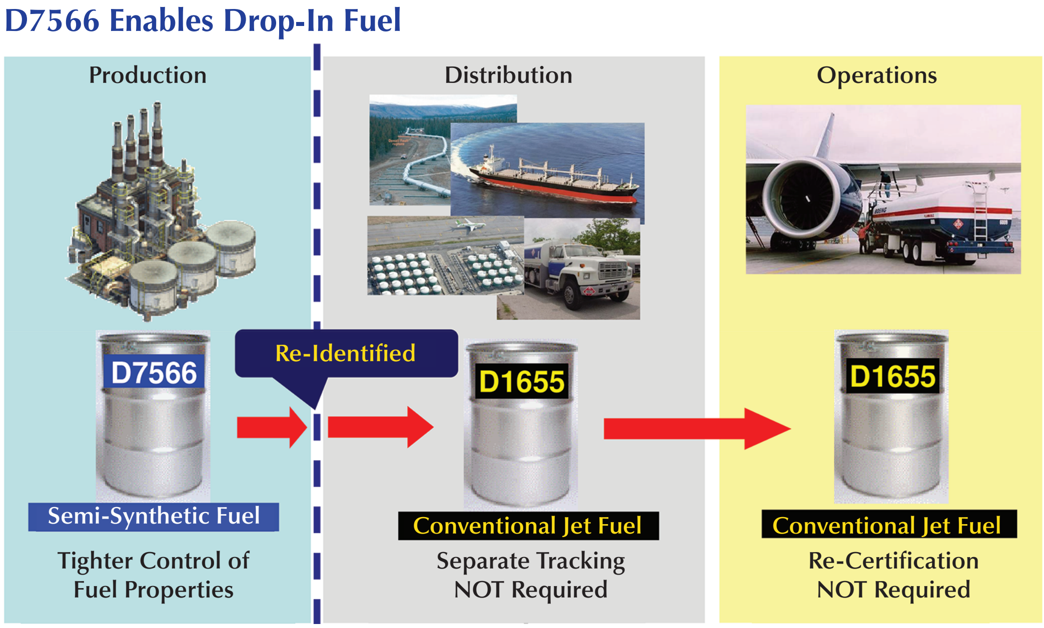

Figure 46 Enabling a Biofuel to Become a Drop-in Jet Fuel.

For commercialization of any new future jet biofuel, other than the ones referred in Annex 1 and 2 and without the airworthiness re-certification of all the aircrafts, it is necessary to have new annexes approved. The ones in preparation by ASTM comprise:

1. Alcohol to Jet (ATJ)
2. Direct Sugars to Hydrocarbons[8] (DSHC)
3. Hydro-treated De-polymerized Cellulosic Jet (pyrolysis) (HDCJ)
4. Catalytic Hydro-thermolysis (CH)
5. Catalytic Conversion of Sugars (CSHC)

Figure 47 and **Figure 48,** reproduced from a recent presentation by Mark RUMIZEN from FAA depict the alternative processes submitted to ASTM.

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[8] Approved by ASTM in June/2014 as Annex 3 - Synthesized Iso-Parraffins (SIP).

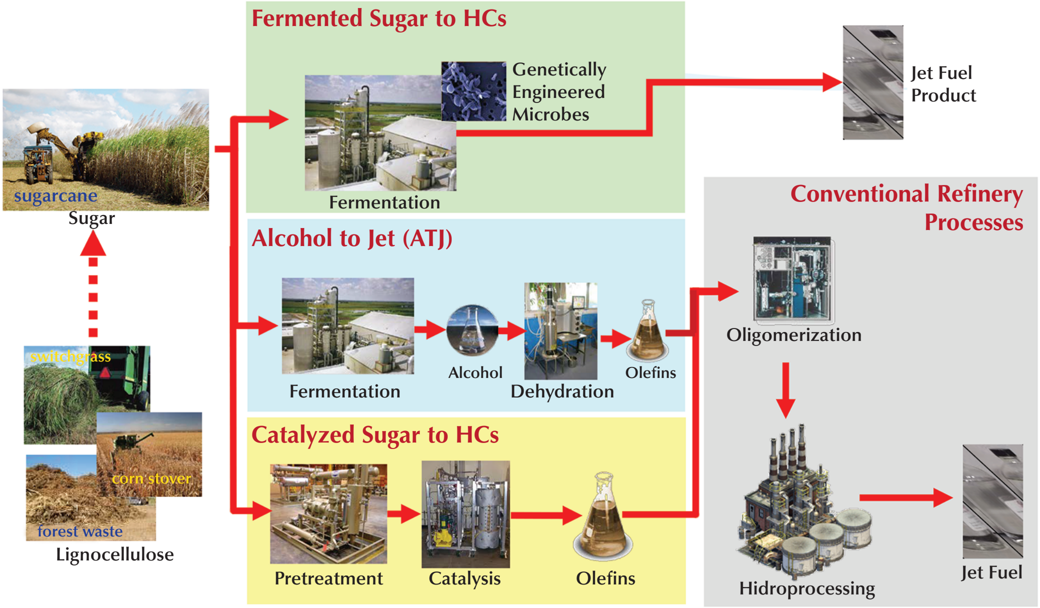


Figure 47 Future Fuels Submitted to ASTM (DSHC, ATJ, CSHC).

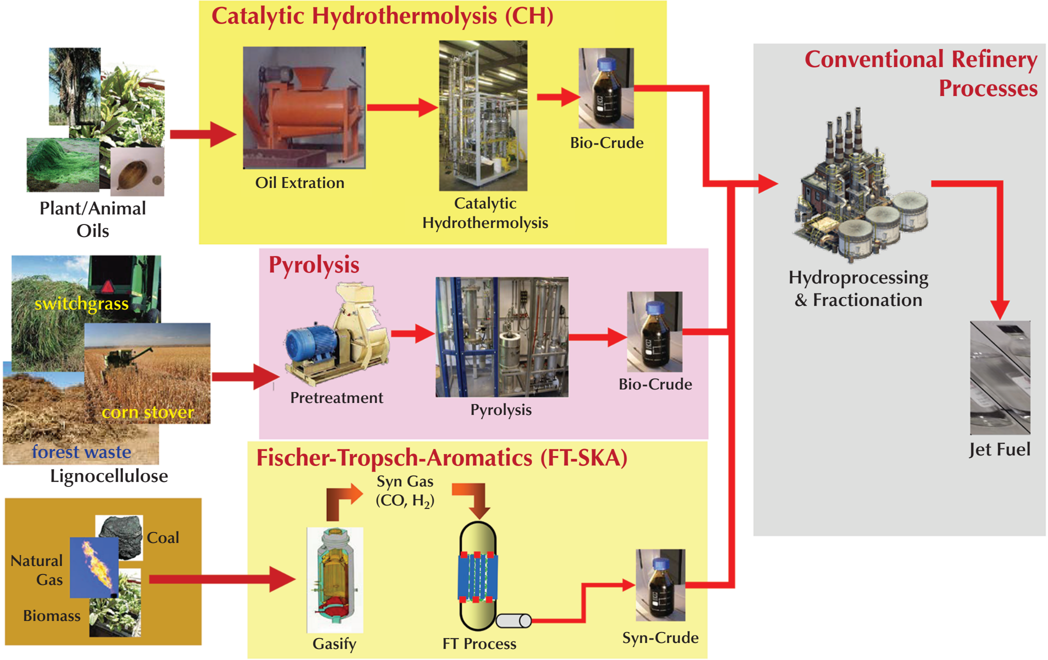


Figure 48 Future Fuels Submitted to ASTM (CH, HDCJ, FT-SKA).

As already mentioned, aviation fuel quality assurance is based on two key concepts: batches and traceability.

The batches that are of the order of ten million liters at refineries have to be homogeneous (density variation smaller than 3 kg/m^3).

At point of manufacture, the producer shall issue a Certificate of Quality to certify that the batch of fuel complies with all of the requirements of ASTM D1655 or D7566 standards as appropriate. The certificate shall cover not only the quantitative limits but also all other requirements set out in the standards.

To certify compliance with the limits, representative samples shall be drawn using appropriate procedures such as those outlined in IP 475 and ASTM D4057.

Documentation shall be provided by the supplier to the purchaser to show that the fuel meets the requirements of these standards and demonstrates traceability to point of manufacture. Upon request, the technical authority or end user shall be provided with the documentation.

Because jet fuel can come into contact with incidental materials during manufacture and distribution, appropriate management of change of the measured values shall be used at manufacturing locations, distribution, and storage facilities to maintain product integrity and detect any contamination, as already presented in **Figure 40** to **Figure 43** for the conventional jet fuel. Exactly the same procedures are to be followed by the drop-in fuel. The only possible differences can occur during the production of the alternative fuels, up to the point where they are blended with conventional jet fuel and certified according to ASTM D7566. The Certificate of Quality issued on this occasion re-identifies the alternative fuel as a jet fuel satisfying ASTM D1655, which is then submitted to the same quality assurance procedures already described.

4.3.3 Requirements for commercialization of alternative jet fuel in Brazil

As already mentioned, the regulatory requirements for jet fuel commercialization in Brazil are set by ANP, particularly by resolution ANP Nr. 37/2009. The Brazilian specification is aligned with the Aviation Fuel Quality Requirements for Jointly Operated Systems (AFQRJOS) that incorporates the requirements of ASTM D1655 and DEF STAN 91-91 and IATA Guidance Material, but not necessarily the last versions. A process for revision of specifications was started in 2012, as presented by ANP at the workshop, of which the objective is to establish the specification for aviation turbine fuel containing synthesized hydrocarbons and the obligations regarding the control of quality to be met by the various economic agents who market the product throughout the Brazilian territory. The specific goals are:

1. specify only the new jet included in ASTM D7566 – Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons;
2. specify the new jet included, using as minimum requirements those of ASTM D7566;
3. define the distribution chain position to make the blend of conventional jet fuel and alternative fuel;
4. define rules for importation of the new jet fuels.

The work group has finished the revision process and, by June 2013, ANP launched the Brazilian Specification and rules for distribution and use of Aviation Biofuels (Resolution ANP Nr. 20/2013).

Certainly, according to the feedstock and process used for obtaining the jet biofuel, and the great number of possible feedstocks in the country, it is quite important to understand the logistics of conventional jet fuel, to choose the best blending point and take advantage of transportation costs of both renewable and fossil fuels.

Another aspect related to commercialization that was tackled in the workshop was the tributary. The presentation by SINDICOM (RODRIGUES FILHO, 2012) has shown that no taxes burden jet biofuel used in international flights, while the fuel used in domestic flights is charged with an average tax among the Brazilian States of approximately 25% of final consumer's price. This percentage includes a Federal tax of 3.2% (PIS/COFINS) over the refinery price plus a State excise tax (ICMS) that can be different among the States, which is a certain percentage of the final price paid by the consumer. **Figure 49** depicts the ICMS variation among the Brazilian States.

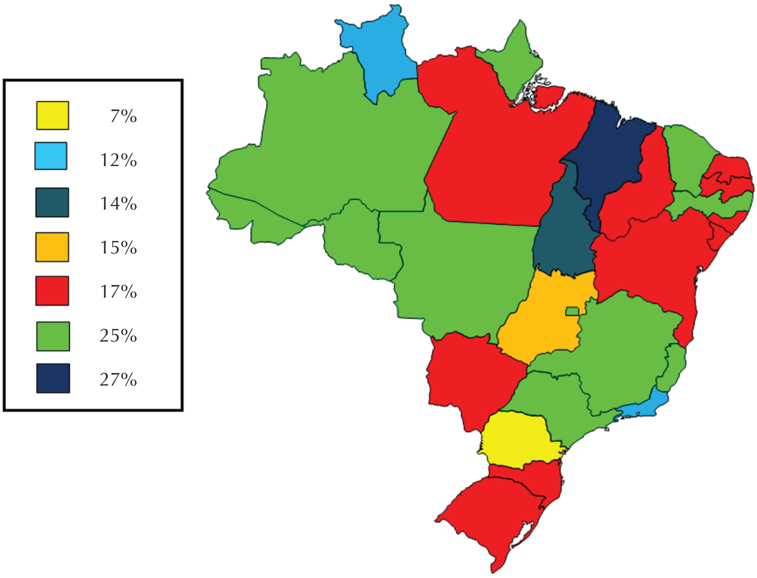


Figure 49 Variation of State Tax (ICMS) Charged on Jet Fuel for Domestic Flight.

5 CRITICAL SYSTEM REQUIREMENTS

5.1 Feedstock

The expert panels pointed out areas that are critical for the production of the potential feedstocks used to make aviation biofuels, taking into account the three pillars that guided this study: the need to have a cost-competitive biofuel, that it be made sustainably, and that its production also brings benefits to the rural communities involved.

Eight main critical system requirements were identified and are listed in **Table 15**.

Table 15 Critical system requirements for feedstocks for jet biofuel production.

REDUCE (OR MAINTAIN) PRODUCTION COSTS	
1) Increase feedstock yield	This is a critical issue for all considered feedstocks, with the exception of the non-agricultural ones, such as industrial wastes and municipal solid waste; for the latter increased production is not goal although improvements in separation process can increase the yield of usable material. Even the most established feedstocks, such as sugarcane, face the challenge of increasing productivity, especially in order to reduce production costs. Through genetic breeding and improvement, and crop management programs, some feedstocks may double productivity by 2020.
2) Reduce feedstock costs	Reducing feedstocks costs is critical to reduce production costs and allow the jet biofuel to be cost-competitive relative to the regular fuel. For biofuels that are already produced in large scale, feedstock costs represent 60% or more of the cost of biofuels; this, probably, will be the same with aviation biofuels. Several of the feedstocks considered do not have established production systems or are in experimental phases and, therefore, have high costs. The potential reduction of costs is variable for each feedstock, however, the means to achieve such reduction were common among feedstocks: genetic improvement and breeding and crop management programs. Improve logistics harvest/collection and transportation is also relevant to reduce costs. Reducing production costs is equally important in the case of the non-agricultural feedstocks, although the means to achieve the reduction are related to logistics and collection, especially in the case of residues and wastes.
ENVIRONMENTAL SUSTAINABLE BIOFUELS	
3) Reduce GHG emissions/ Potential of CO_2 net reduction per hectare	This is a fundamental requirement since it is the main driver for the development and implementation of biofuels for aviation. The potential of reducing emissions in the feedstock production stage is essential in this sense.
4) Energy balance	The ratio between energy input and output is vital in terms of the efficiency of the feedstocks/technologies, and must also be considered along with the potential to reduce GHG emissions.

Table 15 Critical system requirements for feedstocks for jet biofuel production (continued).

ENVIRONMENTAL SUSTAINABLE BIOFUELS	
5) Land use	Land use change (LUC) is a factor accounted in CO_2 emission and thus contributes to climate change. Therefore, the expansion of currently produced feedstocks and the production of new feedstocks should take this into consideration. Depending on type of soil and its current vegetal coverage, implementation of new agricultural activities may have a favorable or unfavorable LUC footprint.
6) Agrochemical use	The environmental impacts (on air, water, etc) of agrochemical use in agricultural feedstock production are an issue to be considered regarding the sustainability of jet biofuels. It is of particular importance the use of nitrogen fertilizers because of the high energy consumption for their synthesis and the significant emission of GHGs associated with their use in the field. Crops that require low or no nitrogen (N) fertilization inputs (soybeans) or have high biomass/N ratio (sugarcane, eucalyptus) have an advantage here. Feedstock production systems that make ease the recycling of nutrients, byproducts, and residues on the field are also preferred. It is also desirable to decrease or have responsible the use of chemical products for the control of plant pest, diseases, and weeds. On the other hand, crop intensification is also an option, through the use of modern technologies and, sometimes increased use of agrochemicals in order to increase plant production. Crop intensification may have a positive overall impact in the sense that it allows the use of less land and, therefore, frees land to other purposes, including food production and areas of natural preservation. Waste feedstocks do not have these issues.
7) Pollution	Pollution is an issue related to environmental and social sustainability of biofuels and, therefore, should also be taken into consideration when analyzing potential feedstocks. In this sense, pollution includes the amount of waste material generated in the production of the feedstock as well as soil erosion and the soil, water, and air contamination due to agriculture practices and processing of feedstocks.
IMPROVE REGIONAL DEVELOPMENT	
8) Job creation and quality	The generation of jobs and the improvement of the quality of jobs (through formalization, training, etc) are also fundamental when considering potential feedstocks.

Efforts in R&D are important to increase yields and reduce costs but yields can improve substantially by just applying current knowledge as the data of **Table 16** indicate. The Strategic Committee of Soybean Brazil (CESB) promotes a contest with farmers in order to stimulate performance. The average soybean yields of the best farmers in the last two contests are more than double those of Brazilian average and some farmers have obtained yields above 6 t/ha. Such output may improve the competitiveness of soybean as feedstock for jet biofuel production, but costs and environmental impacts of these high yielding systems must be evaluated.

Table 16 Potential for increasing soybean yields in Brazil in rainfed areas.

SOYBEAN PRODUCTION CONDITIONS	SOYBEAN YIELDS IN YEAR (kg/ha)				
	2008/09	2009/10	2010/11	2011/12	2012/13
Brazilian average yields	2,628	2,928	3,114	2,646	2,934
Average of 10 best farmers1	4,668	5,286	5,724	5,730	6,228
Best farmer1	4,968	6,504	6,036	6,522	6,630
Difference best farmers/Brazilian average (%)	78	81	84	117	112
Number of participating farmers	140	800	1,185	1,314	1,198

Notes:

1- Best farmers yields obtained in a farmer competition organized by CESB (Strategic Commitee of Soybean Brazil). According to CESB's rules the field must have between 5 and 10 ha and be managed in a similar manner to that of the rest of the fields enroled in the contest. Source: htttp://www.desafiosoja.com.br/IVForum.aspx (accessed on 2013-8-20)

5.2 Refining Technologies

The critical high level parameters in terms of the goals of the project are listed in **Table 17**.

Table 17 Critical system requirements for refining technologies for jet biofuel production.

REDUCE (OR MAINTAIN) PRODUCTION COSTS	
1. Increase the yields of each step of pre-treatment of biomass, conversion (chemical or biological) and final synthesis of jet biofuel	This is critical for every technology considered, since the cost of the feedstocks is responsible for a large part of the final cost of the fuel and they cannot be largely wasted as by-products. For the termochemical conversion of lignocellulosics the price of feedstocks is lower, however, the investment costs for reactors is rather high.
	Reduced overall cost would be achieved by converting biomass into refinery ready material that uses today's infrastructure and distribution channels
ENVIRONMENTALLY SUSTAINABLE BIOFUELS	
2. Reduce GHG emissions and CO_2 footprint of the jet biofuel	These are requirements for implementation of biofuels for aviation. The potential for simple and energy economic/profitable technology is fundamental in this sense.
3. Energy balance	The ratio between energy input and output of the technology is fundamental and should also be considered along with the potential to reduce GHG emissions.
IMPROVE REGIONAL DEVELOPMENT	
4. Industrial employment	The generation of jobs and the improvement of the quality of jobs (through formalization, training, etc.) are also fundamental when considering the different technologies.

6 LARGE TECHNOGICAL AREAS

6.1 Feedstock

Four main large technological areas were identified (**Table 18**) that contribute to achieve the critical system requirements listed in **Table 15** (see section II.2). The most important areas are plant breeding and improvement, and crop management.

Table 18 Large technological areas for feedstock production.

AREA	LIST OF THE RELEVANT TOPICS
1) Plant breeding/ improvement	new traits, transgenic technologies, tolerance to adverse climatic conditions, tolerance to pests, superior genotype selection, cloning systems, hybridization, new crop varieties, specific varieties for biomass production.
2) Crop management	no-tillage, minimum tillage, fertilization, precision agriculture, harvesting systems, mechanization, soil management and farm practices, water use efficiency
3) Residue use and by-products	alternative uses for residues, recycling of nutrients, development and use of by-products, equipment for application of by-products.
4) Residues and wastes collection and management	in-site collection (where the residue is produced), transportation and logistics of residue, storage, pretreatment, machinery/equipment, landfill emissions.

6.2 Refining Technologies

6.2.1 Pre-treatment processes

The use of lignocellulose materials (lignin, hemicellulose and cellulose) for second generation biofuels has not yet become an industrial reality due to the lack of efficiency and low cost technologies (DIAS, 2011). Even massive use of the first generation fuels (from sugars and vegetable oils) from biomass have not yet reached their full potential, due to a series of difficulties, mainly related to sustainability, food versus fuel competition and land use. The heterogeneity of lignocellulosic material and the broad variation in chemical composition of the raw material can be overcome by a variety of pretreatments to produce a more uniform structured material, which only then would be transformed into desirable intermediates via secondary conversion processes.

An effective pre-treatment, according to Galbe and Zacchi (2010), must yield high concentration of soluble carbohydrates; achieve high digestibility for hydrolytic enzymes; produce low concentration of degraded products of sugar and/or lignin; offer high solids content, require low energy requirement and/or allow energy recycling; and low capital and operational costs.

Amongst these are physical or also named mechanical (fractionation, crushing, extraction), chemical (acid, alkaline, organosolv), physicochemical (steam explosion, hydrothermolysis) and biological (enzymes, microorganisms) or a combination of pretreatments that prepare large volumes of biomass and condense them to lower volumes. Small pretreatment units can be installed at the feedstock production farms to initially transform the biomass and its products can be then transported or used immediately by the conversion plant.

6.2.2 Conversion Technologies

6.2.2.1 Gasification

The gasification of carbonaceous materials has been commercially done for over 50 years; however the synthesis gas has to be catalytically transformed into liquid fuels. To do this in an economical way, the gasification has to be done under pressure which represents some technical risks and needs larger plants. Another possible route for lignocellulosic biomass is to start with pyrolysis, obtaining bio-oil and bio-char, intermediate products that could be transported economically through larger distances, to be then submitted to gasification and synthesis by the Fischer-Tropsch process. The investment cost for the FT alternative is given as high (1€/L for a 200 million liters/year capacity) (KUMAR et al., 2009).

6.2.2.2 Fast Pyrolysis

Fast pyrolysis converts biomass into a liquid product (pyrolysis oil or bio-oil) which needs to be upgraded to produce liquid fuels. According to Mohan et al. (2006), fast pyrolysis of biomass produces bio-oil, which is easily transported and stored and could then be upgraded by hydroprocessing or fractionation (distillation) and commercialized according to the properties of each fraction obtained. Bio-oil could also be transported to a Syngas refinery to be further processed by Fischer-Tropsch technologies (ZHANG et al., 2012).

Charcoal processing is also considered a pretreatment that increases the energy density of the biomass. Therefore, pretreated material is more easily stored and transported (i.e. bio-oil, hemicellulose hydrolysates, charcoal) and potentially better distributed to larger refineries. Fast pyrolysis is preferred. There are several demonstration plants being tested outside Brazil. Bio-char is a very valuable active carbon source (VAMVUKA, 2011).

6.2.2.3 Liquefaction

Biomass conversion to liquid fuels (bio-oil) via solvent liquefaction, pyrolytic processes and catalytic hydroprocessing achieves good yields of liquid hydrocarbons but this is mostly experienced on a bench scale and small pilot plants. Improved understanding of process steps and properties still needs to be developed, since process economics are promising in the current economic environment. Solvent liquefaction seems to be promising as no hydrogen or catalysts are needed and the conversion conditions are rather moderate. Patents have shown that the level of upgrading of bio-oil depends on the final use of the product, which will depend on the properties of the desired liquid fuel (MOHAN et al., 2006). **Figure 50** presents a bio-platform scheme.

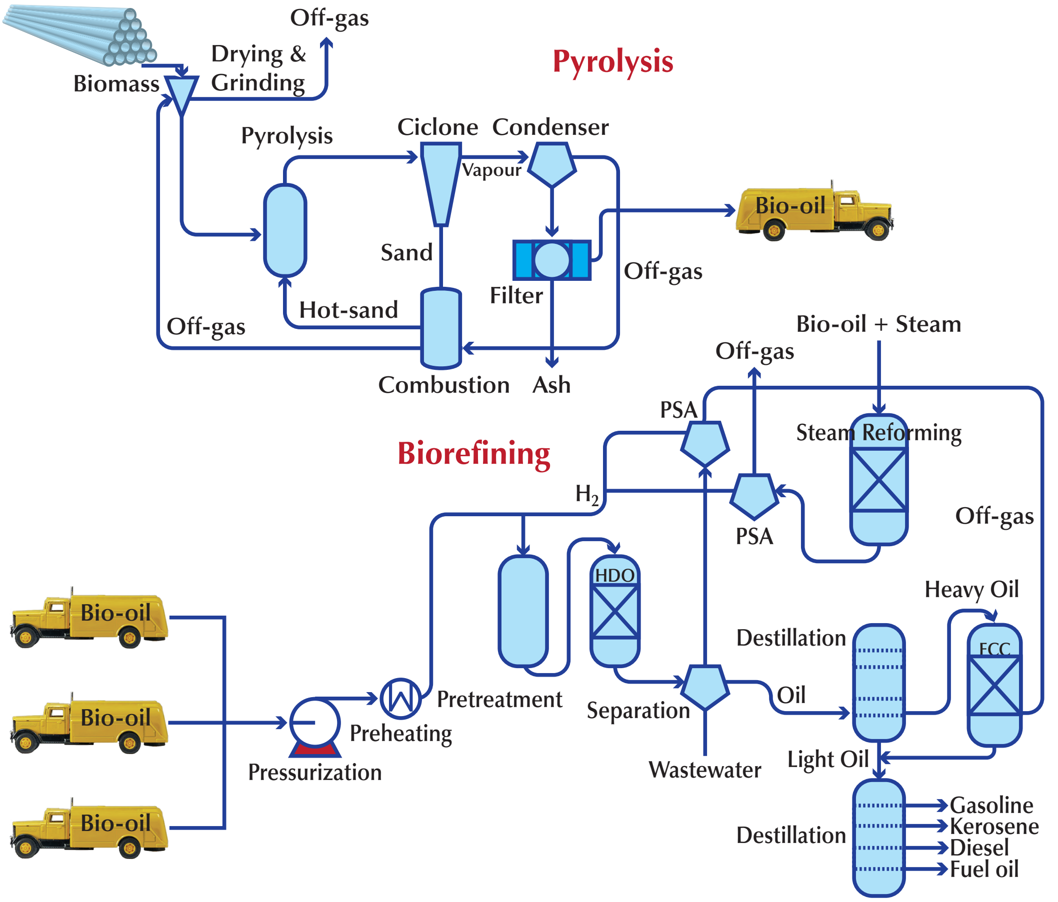


Figure 50 Bio-oil platform. Source: Elliot, 2010.

6.2.2.4 Hydrolysis

Hydrolysis with a low concentration of acid and steam explosion processing is able to disrupt the hemicellulose fraction and release lignin and cellulose to some extent and two main products obtained are the lignin + cellulose fraction and the hemicellulose-rich hydrolysate. Acid hydrolysis is valuable for pre-hydrolysis. The pre-hydrolyzed cellulose can then be hydrolyzed enzymatically. A large number of pilot and demonstration plants exist throughout the world. There are different technological concepts aiming to increase the amount of solids in the reactors (**Figure 51**) (MOSIER et al., 2005).

Byproducts as furfural, hydroxymethylfurfural, organic acids and others can be formed during hydrolysis, which inhibit fermentation (**Figure 52**). The concentration of inhibitory byproducts and as well of the desired sugars (pentose sugars in monomeric or oligomeric forms) in the hydrolysis streams, obtained after the steam explosion pretreatment, can be adjusted by setting the process conditions. Therefore, hemicelluloses sugars would be released in the liquid phase and the solid cellulose is further enzymatically treated. Despite the differences in acid pretreatments (inorganic, organic acids, impregnation) and steam treatments, it is possible to find a set of pretreatment conditions that allows the biomass processing or mixture of them to be converted with satisfactory yields of streams, and offering the solid cellulose ready for enzymatic treatment.

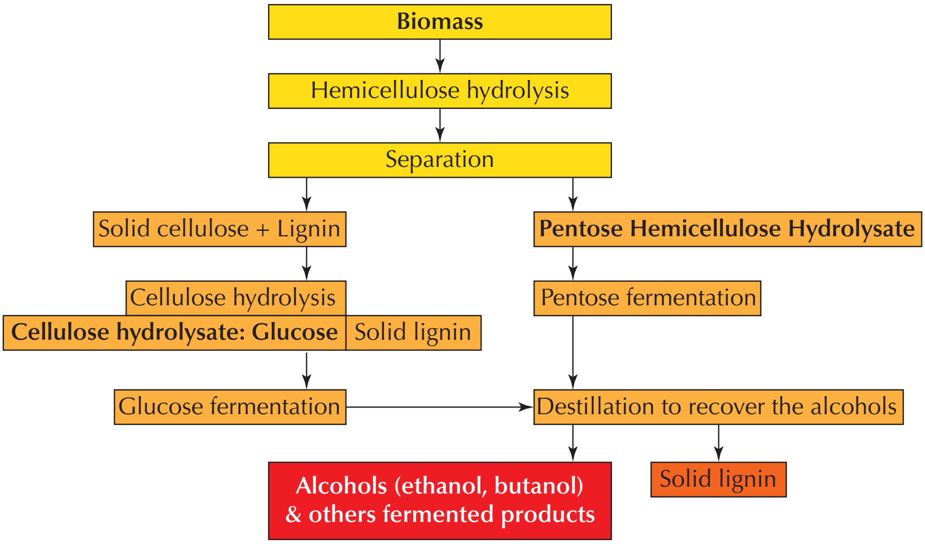
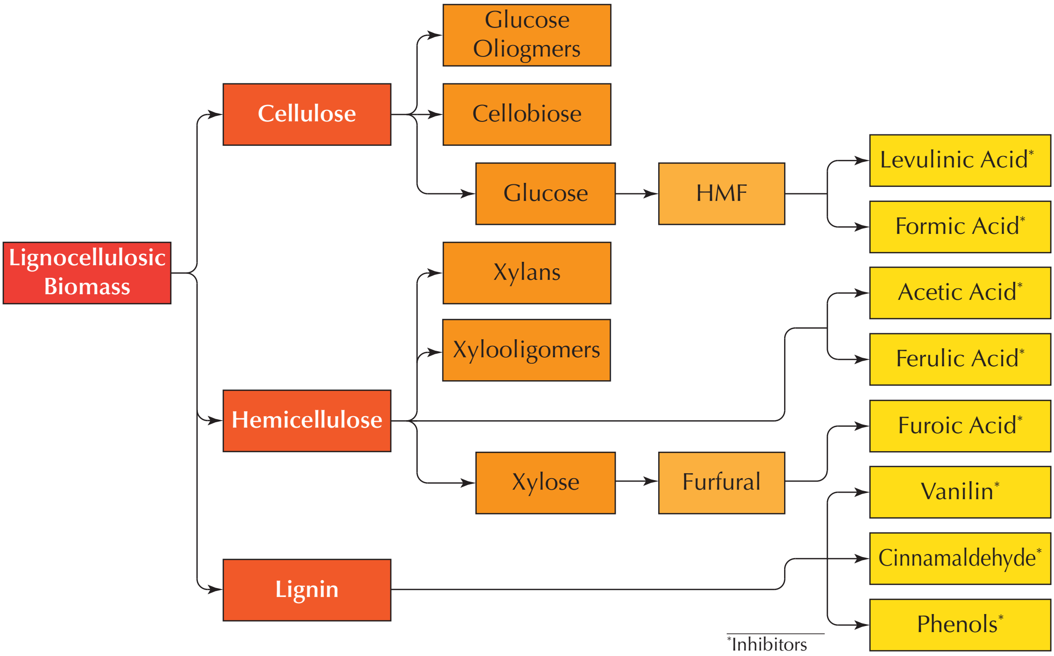


Figure 51 Flow chart for the production of two hydrolysates: hemicellulose pentose-rich hydrolysates and cellulose glucose-rich hydrolysate. Products are generated from both hydrolysates via fermentation or chemical pathways.



*Inhibitors

Figure 52 Product potential inhibitors to microbial growth from the cellulose, hemicellulose and lignin fractions of lignocelluloses biomass during pretreatment. Source: adapted from Modenbach; Nokes, 2012.

Enzyme hydrolysis technology is still being optimized and the price of the enzymes needs to be reduced further. There are some pilot and demonstration plants throughout the world, using different technological concepts aiming to increase the amount of solids in the reactors, to produce them in-house and to recycle enzymes or to do simultaneous saccharification/ fermentation (SSF).

Industrial cellulases and xylanases are well-known commercial products, tailor-made according to the target commercial application. Very significant progress in the engineering of enzymes using advanced biotechnology techniques, like directed evolution and rational design studies have opened new markets, with enzymes being increasingly tailored for specific applications and higher activities. Protein engineering of lignocelluloses-degrading enzymes, including mutagenesis of potential active centre residues with subsequent kinetic analysis, has been used as a tool in the study of the catalytic mechanism and improvement of some properties of industrial enzymes. The "Improved low cost cellulase for biomass conversion" project, developed in the US in 2000–2003, aimed to reduce the cost of enzymatic hydrolysis, by reducing enzyme costs 10 fold. In-house enzyme production is also considered as an alternative to reduce the cost (KOVACS et al., 2009). A recent Brazilian project was developed from 2006 to 2007, aiming to produce in-house fungal enzymes, by submerse and by solid fermentation to reduce their costs (BON; FERRARA, 2007).

6.2.2.5 Fermentation to alcohols

The original feedstocks for this route are sugars and starches; however other alternatives include lignocellulosics, industrial waste gases and municipal solid wastes (MSW). Starches and sugars may be converted to alcohols through direct fermentation and industrial waste gases rich in CO can potentially be converted to alcohols by gas fermentation. Lignocellulosic biomass may be converted to alcohols after being hydrolyzed to simple sugars, followed by fermentation, or by gasification to produce synthesis gas ($CO + H_2$), followed by gas fermentation. A fraction of the organic MSW is fermented to carboxylic acids and further transformed into ketones and hydrogenated to secondary alcohols (KANITZ; KESSELRING, 2002).

These different wastes can potentially be used as feedstock for fermentation to alcohols or other chemical building blocks to be further converted to jet biofuel by a specific technology. Also the integration with conventional feedstocks should be considered to reduce the cost of the jet biofuel, when logistics for transport is designed.

1. **MSW**: The technology may be appropriate to produce liquid fuels by fermentation to organic acids, alcohols or other chemical building blocks. The technology will depend on the kind of waste separation and the kind of fraction considered.
2. **Industrial Residues**: There is no available inventory on residues from the Brazilian industry at the moment. The capabilities have been studied as feedstock for fermentation to alcohols or other chemical building blocks. The technology will depend on the kind of separation and purity considered.
3. **Gases**: The idea is to harvest carbon monoxide to feed microorganisms in a bioreactor, which would be converted to alcohols to be further transformed into liquid fuels. Scaling-up has been planned in China (NIGRO, 2012).
4. **Sewage**: The strategic potential is considered very low and the technical risk is very high. The technology may be appropriate to produce liquid fuels by fermentation to alcohols or other chemical building blocks. No capabilities were detected.

6.2.2.6 Lipids from carbohydrates

Microbial lipids (microalgae, bacteria and yeasts): The feasibility of waste materials and energy-dedicated vegetables to be efficiently biologically converted into valuable chemicals or biofuels with higher added value or into building blocks for industrial needs depends on the capability of microorganisms to use pentoses besides of hexoses, and to stand the most common impurities originated from them. It is widely known that organic compounds produced by fermentation are alternatives for substitution of fossil derived chemicals, since substrates from nature, i.e. carbohydrates, can be converted into building blocks (organic acids, alcohols and others) which allow producing polymers, resins, and fuel. The monomers glucose, xylose and arabinose, main sugars from lignocelluloses, are abundant in nature, especially from agro-industry wastes (BLANCH, 2012).

Photosynthetic microorganisms (algae and cyanobacteria) and fungi produce materials with high-lipids content, have a shorter doubling time and allow continuous harvesting. Microalgae and cyanobacteria have recently called a lot of attention of the media, due to the lower quality requirements for land (lower demand of fertile land to produce, in theory, the same amount of lipids than oleaginous plants) (LAM et al., 2012). The literature describes the production of lipids from molds. In particular, oleaginous microorganisms also can be used to produce a great deal of lipid, up to 70% lipid of the total dry cell weight under certain conditions (BIGNAZZI et al., 2011). For this reason microbial feedstock is gaining attention and research investments from petrochemical industry.

Today, the dominant cost factor in microbial biofuel and commodities is the raw material; however several agricultural crops offer non-edible wastes, i.e. corn cobs, wheat and rice straw and sugarcane bagasse. Easy transport of short distances and good logistics allow the employment of suitable treated sugarcane bagasse to be used as feedstock (KOSKINEN; TANNER, 2012).

Since lignocellulosic biomass is the most abundant raw material from agricultural residues, it is very commonly left in the fields due to the original design of equipment for harvesting. Its utilization is an important option to be considered in industrial biotechnology and biorefining, to reduce the costs, to avoid competition with the food and feed industries and minimize environmental problems due to excessive volume of wastes to be disposed. Several authors have evaluated the viability of their use to produce chemicals and commodities (GOPINATH et al., 2012).

6.2.3 Technologies to produce jet biofuel

6.2.3.1 HEFA (hydroprocessed esters and fatty acids)

HEFA is sometimes also called HRJ (hydroprocessed renewable jet fuels) or HVO (hydrogenated vegetable oils), which are produced by “refining” lipid material, much like the way petroleum is refined today. The hydroprocessing of lipids, mainly the oils and fats (from plants, microbial or animal) involves converting them into hydrocarbons by the addition of hydrogen.

The first step converts the lipids to fully saturated hydrocarbons, or synthetic paraffins and propane, by saturating carbon double-bonds with hydrogen and removing oxygen as water. These paraffins are then selectively cracked and isomerized to produce primarily diesel, jet fuel, gasoline and naphta. This process is a qualified process for renewable drop-in jet fuel in the market, and meets the required specifications (KAUL et al., 2012).

This process can be integrated into existing fossil fuel refining facilities and operated at similar costs of petroleum refining. It can also be added to the first generation biodiesel production facilities, or built from scratch in stand-alone refineries. HEFA fuels are ASTM certified for commercial use in up to a 50/50 blend with conventional jet fuel (RENEWABLE JET FUELS, 2013). Residues like used cooking oil, or the industrial sub-products tallow and yellow greases, can be used as feedstock. Hydrogen demand for different feedstock qualities varies, resulting in different conversion costs for diverse raw materials like palm oil, animal fats, camelina, jatropha, etc. (MILLER, 2010).

Investment cost for hydro-processing is considered to be lower than for the Fischer-Tropsch process, but the cost of the raw materials can represent more than 70% of total cost. Vegetable oil market prices are following petroleum price developments (OVALLES et al., 2011).

Other possibilities of feedstock for HEFA are microbial lipids, obtained by fermentation of fermentable sugars or from hydrolysates of lignocellulosic material. Some species of oleaginous yeasts, bacteria and heterotrophic microalgae can store up to 70% (w/w) of lipids in their cells (dry mass). The economic possibilities of these last alternatives are strongly dependent on the price ratio of sugar to ethanol to vegetable oils. The technology is known, however the improvement of the stability of the transgenic yeast/algae would be very much desirable to improve the performance of large bioreactors. These technologies are available to produce lipids directly from sugar, which then require hydro-cracking and are available in pilot plant stage. Commercial risks will be reduced when cellulose/lignocelluloses can be used as feedstock as they will benefit from second generation sugars.

HEFA technology is well developed, however expensive hydrogen is needed. When the process is done in a petro refinery plant, a hydrogen-rich stream is often available. The amount of hydrogen needed varies with different chemical structures of feedstock oils (MADSEN et al., 2011). This mixture produce hydrocarbons at different ratios, which can be fractionated (HUANG et al., 2011).

The percentages of the synthesized hydrocarbons (diesel, jet fuel, gasoline and naphta) vary much with the synthesis conditions, however they follow the Schultz-Flory distribution and no reliable values can be found in the literature.

Another process which converts lipids to liquid fuels is the thermal cracking of fatty materials, which gives good results, however much more development is needed to use it in a technical industrial scale. Used cooking oil is better used for thermal cracking since only filtration is necessary. This technology produces a mixture of hydrocarbons attending the requirements for diesel (about 10%), naphtha (10%) and 35% jet fuel, which are separated by distillation.

6.2.3.2 Alcohol to jet (ATJ)

ATJ is made via alcohol dehydration/oligomerization which involves linking short-chain alcohol molecules (e.g. methanol, ethanol and others) together to form jet-fuel range hydrocarbons. There are several chemical reactions that can be employed to oligomerize alcohols. In each of these processes, water and/or oxygen are removed from the alcohol molecules, and hydrogen is added because the starting alcohol volume is reduced in order to produce a marginally more valuable hydrocarbon jet fuel (at current market prices), the economic rationale of these conversions must be critically examined on a company-by-company basis as shown in **Figure 53** (STREET et al., 2012).

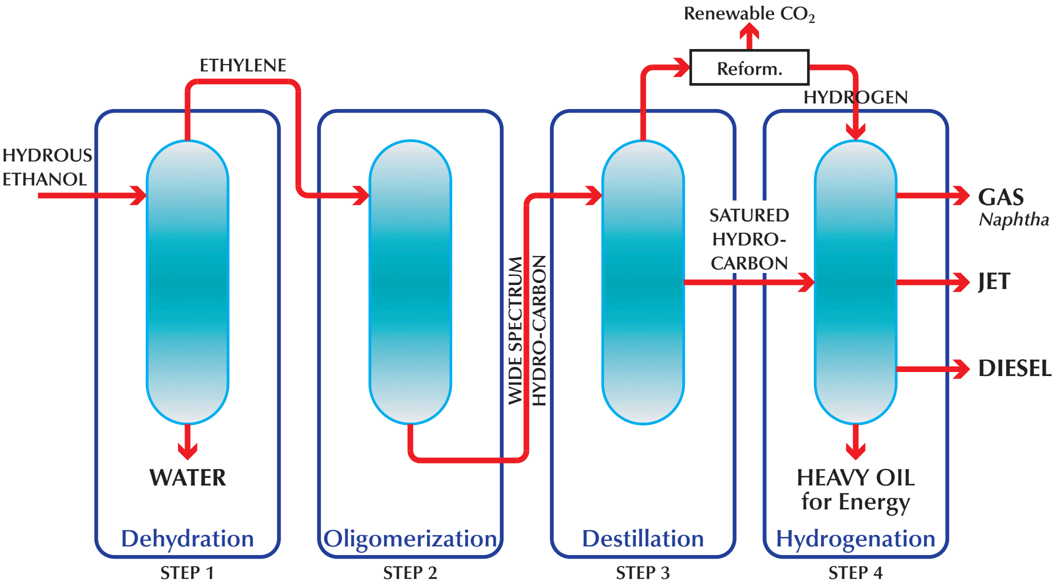


Figure 53 Steps of AJT process. Source: Weiss, 2012.

Different research groups have developed specific catalysts for the direct and high-yield conversion of bio-ethanol to fuel additives, rubbers and solvents. With increased availability and reduced cost of bio-ethanol, conversion of this particular bio-based feedstock to high valuable fuels and chemicals has been an especially important research goal. Currently, research on bio-ethanol conversion to value-added chemicals focuses mainly on ethanol dehydration to ethylene, or ethanol dehydrogenation to acetaldehyde and then to acetone via Aldol-condensations pathways (SUN et al., 2011).

The ATJ process, which is in the process of approval by ASTM, still needs subsidies/mandates, if sugar is employed as the feedstock, due to the high market price of sugar. However when cellulosic sugar or low cost alcohol from other sources such as industrial waste is available, the commercial risks can be reduced. The alcohol intermediates may be methanol, ethanol, butanol, isopropanol, other alcohols or a mixture of them (PARGHI et al., 2011). Large advantage in costs would be achieved with the minimization of the operation steps of this process.

The percentages of the synthesized hydrocarbons vary much with the synthesis conditions and are ruled by the Schultz-Flory distribution. According to Byogy, this technology produces a mixture of hydrocarbons attending the requirements for diesel (about 10%), naphtha (10%) and jet fuel (35%), which are separated by distillation.

Due to the large Brazilian experience in producing ethanol from sugarcane and the existence of a well-established agro-industrial sector dedicated to this subject, the natural reference prices for liquid biofuels and lignocellulose concentrated biomass probably will be ethanol and sugarcane bagasse. Worth mentioning is that the ethanol production in Brazil in 2011 was approximately 18 billion liters, amount that, in energetic terms, is more than one and a half times the whole aviation fuel consumption in the same year.

6.2.3.3 Syngas/Fischer-Tropsch

The synthesis gas (CO and H_2) is converted into hydrocarbons by growing the carbon chains, catalyzed by metal supported catalysts (heterogeneous catalysis), according to reaction (1).

$$CO + 2H_2 \rightarrow —CH_2— + H_2O \tag{1}$$

Fischer-Tropsch paraffinic kerosene can be produced from lignocellulosic biomass through gasification followed by gas cleaning and synthesis over appropriate catalysts (**Figure 51**). The process is approved for a 50% blend by ASTM. Although raw material cost in this field is very low, the transportation cost is important and limits the size of the processing plant, with large implications on investment costs (ALVES, 2011).

The product obtained by the Fischer-Tropsch synthesis is a mixture of hydrocarbons with chains of different sizes (**Figure 54**), from light gases to high molecular weight greases (LUQUE et al., 2012; KLERK, 2011). In order to achieve commercial specifications for fuels, the liquid mixture of hydrocarbons obtained must be appropriately separated and, as required by the market, also needs conversion steps for transforming molecules of high molecular weight into molecules of lower molecular weight hydrocarbons or adding other compounds (derived from traditional oil refining) to assist in adjusting the properties required for the specified fuel (Bartholic, 2000). The percentages of the synthesized hydrocarbons vary with the synthesis conditions and are ruled by the Schultz-Flory distribution.

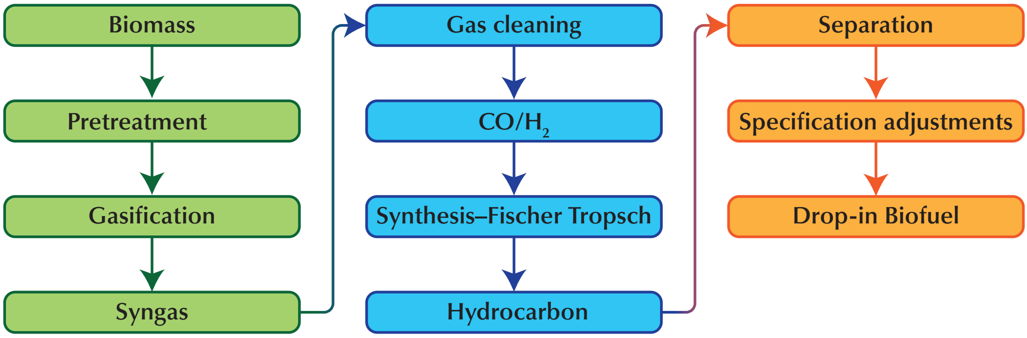


Figure 54 Operations required transforming biomass into drop-in jet biofuel by Fischer-Tropsch conversion.

Synthesis of methanol or dimethylether as a platform chemical to produce hydrocarbons is another route to jet biofuel (OLAH et al., 2012). **Figure 55** presents a the chemical platform to syngas.

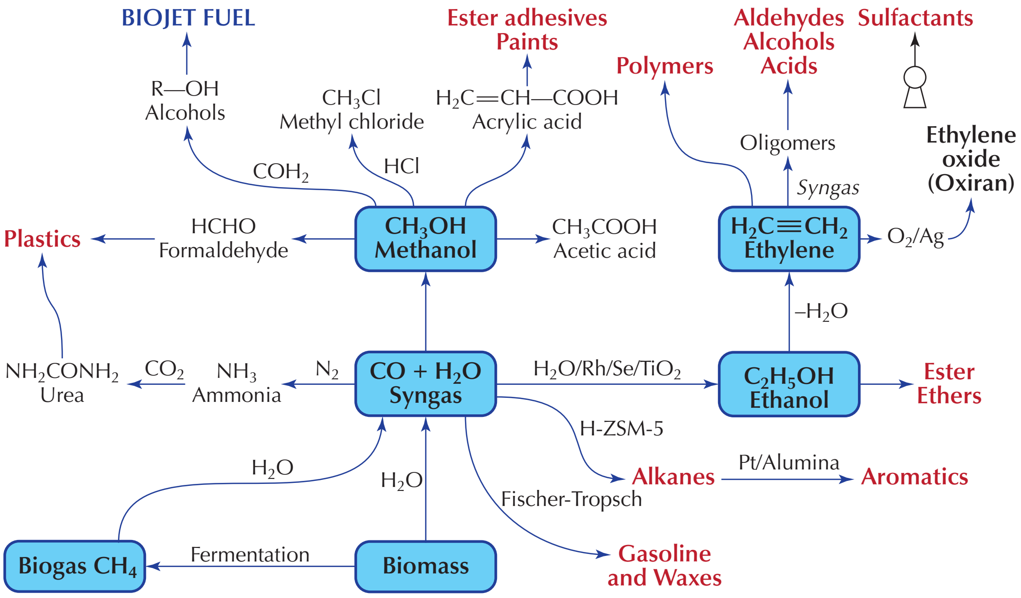


Figure 55 Fuels and chemicals from a biomass Syngas-Methanol platform. Source: adapted and modified from Kamm et al., 2006.

6.2.3.4 Direct Sugar to Hydrocarbon (DSHC)[9]

A biotechnological approach was developed to directly bioconvert sugars by fermentation to farnesene (DOUGLAS et al., 2007), which can further be hydrogenated to farnesane (a branched paraffinic hydrocarbon containing 15 carbons (**Figure 56**) with desirable characteristics for jet fuel. This hydrocarbon has already been registered with the United States E.P.A. for widespread use in a 35% blend with petroleum diesel.

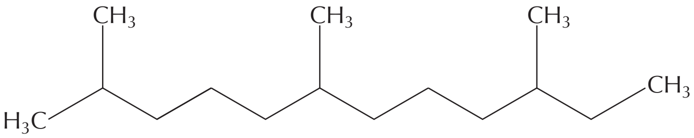


Figure 56 Farnesane molecule structure.

Farnesene is transformed into farnesane through a combination of hydroprocessing and fractionation operations (**Figure 57**). Hydrogenation of the farnesene feedstock with hydrogen in a catalytic bed is needed in order to reduce the double bounds. Fractionation consists in a gas/liquid separation (to remove hydrogen from the resulting hydrogenated compounds) and isolation of farnesane in order to reach jet fuel specification targets.

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[9] Now denominated Synthesized Iso-Parraffins (SIP) and approved by ASTM as Annex 3.

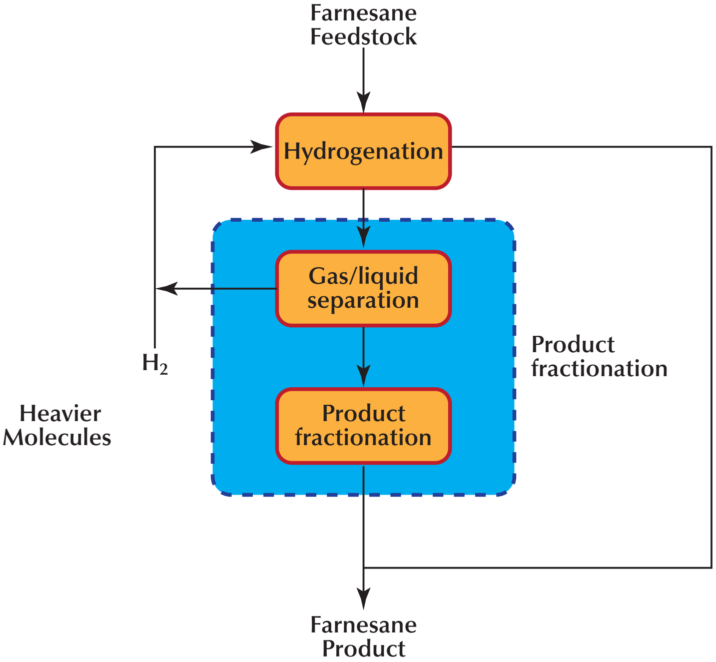

Figure 57 Simplified overview of the process to produce DSHC fuel. Source: Amyris, 2012.

A demonstration flight using a blend of 20% farnesane DSCH, 30% C10 hydrocarbon and 50% jet fuel was performed in Brazil. The producer of the DSHC technnology (Amyris) is seeking ASTM qualification for a low blend of farnesane into Jet A/A-1. The work group has completed the analyses of physical-chemical property and fuel specification data, according to ASTM D1655 and ASTM D7566, and is now undergoing Fit-for-Purpose testing at the Air Force Research Lab (AFRL). The resulting research report will be used to prepare a proposed ASTM DSHC fuel specification[10].

In theory, it is expected that the efficiency for this pathway by aerobic fermentation is that 3 kg of sucrose are converted into 1 kg farnesene, considering both, 100% biological conversion and 100% purification with zero losses and 100% efficiency of the hydrogenation step (4 molecules of H_2 for each farensene). However, lower conversion is presently achieved. The use of lignocellulose hydrolysates is being evaluated to replace sucrose.

6.2.3.5 Catalytic bio-oil upgrading

Different types of catalyst have already been investigated, both mesoporous and microporous. It seems that the ZSM-5 catalyst is a promising catalyst. Bio-oil upgrading has also been investigated using hydrodeoxygenation and catalytic cracking processes. For the deoxygenation, the research challenge is to design novel catalysts with enhanced activity and selectivity and, especially, better stability to deactivation. The partially deoxygenated

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[10] In fact already approved by ASTM (June/2014) as Synthesized Iso-Parraffins (SIP), permitted for blending of up to 10% with conventional jet fuel.

bio-oil is probably the best solution, since it can be further upgraded by co-processing with petroleum. For the catalytic cracking process the challenge is to design catalysts with less coke formation or to use bio-oil with less phenolic components (DE GRUYTER, 2012).

6.2.3.6 Hydrogen necessity of different conversion technologies

The hydrogen, necessary to convert the feedstocks into biofuels, may be produced within the conversion process or has to be added externally. Gasification of any biomass certainly produces enough hydrogen for the transformation of the synthesis gas into jet fuel (TIJMENSEN et al., 2002). Fast pyrolysis or liquefaction produces a bio-oil which has a relatively large percentage of formic an acetic acid, which can act as a hydrogen source for the transformation of the bio-oil into jet fuel (KARIMI et al., 2011). In these cases no expensive external hydrogen is needed. On the other hand, hydrogenation of farnesene (Amyris), hydroprocessing of fatty acids (Solazyme) or their esters (bio-diesel or algal oil) require expensive external hydrogen, which makes the jet fuel more expensive. Acid catalyzed dehydration of ethanol, obtained by fermentation, to jet fuel also requires external hydrogen; however the quantities are rather small.

7 TECHNOLOGY DRIVERS

7.1 Feedstock

In the experts panel the technology drivers were discussed considering the three pillars set beforehand for jet biofuel production within this roadmap: a) reduce production costs, b) ensure that biofuels are environmentally sustainable, and c) that biofuel production improves rural development. The main technology drivers, summarized in **Table 19** to **Table 22**, are presented individually and distributed according to the critical system requirements. Only drivers explicitly mentioned in the workshop by the speakers are presented below.

For plant feedstocks, genetic improvement and crop management practices were the main technological to meet most critical systems requirements. The technology drivers varied according to group of plants or specific crops, because crops are in different stages of technological development and cultivation in Brazil. Sugarcane, soybeans and eucalyptus are widely cultivated and have strong R&D bases, but jatropha and camelina are relatively new crops in Brazil. For instance, for jatropha, detoxification of residues, and mechanized harvest were considered important drivers to reduce feedstock prices. Different aspects or problems were emphasized by the experts assembled in different groups. However, it seems clear that most improvements can be obtained with research in areas such as plant breeding and agricultural practices. The use of modern technologies such as molecular biology and precision agriculture can speed up progress.

Technology drivers for improving rural development were not pointed out in most expert panels. The prevalent opinion was that modernization of agriculture per se, which is necessary to produce feedstock for aviation biofuel, tends to decrease job numbers for unskilled laborers but increase overall opportunities in the farms and, especially, in the small towns and rural communities. The improved infrastructure, the increased consumption of seeds, machines, agrochemicals, services, etc, will foster economic growth. In addition, more organized businesses, both at the farm level as well as that of suppliers and other components of the biofuel chain, tend to offer better quality jobs, which abide by labor laws and regulations.

Table 19 Oils Group.

GOAL	OIL CROPS	CRITICAL SYSTEM REQUIREMENT (CRS)	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Reduce Production Costs	*Soybean*	CSR#1 Increase feedstock yield and CSR#2 Reduce feedstock Costs	Genetic improvement	- Drought tolerance
				- Rust resistance
	Palm	CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs	Plant breeding	- Resistance to bud rot
				- High efficiency cloning system
			Seed production	- Expand seed production

Table 19 Oils Group (continued).

GOAL	OIL CROPS	CRITICAL SYSTEM REQUIREMENT (CRS)	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Reduce Production Costs	*Camelina*	CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs	Genetic improvement	- Suitable new camelina varieties
				- Oil content increase
	Jatropha	CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs	Genetic improvement/ breeding	- Superior genotype selection, matched to local conditions: even ripening
			Crop management	- Disease control
				- Fertilization
				- Spacing
				- Growth regulators
				- Pruning
				- Phenology management
				- Mechanized harvest
			Residues	- Residues detoxification
				- Alternative uses for residues
Environmental Sustainable biofuels	*Soybean*	CSR#3 Reduce GHG emissions/Potential CO_2 net reduction per ha	By-products	- Use of biodiesel by machinery
	Camelina	CSR#3 Reduce GHG emissions/Potential CO_2 net reduction per ha	Crop management	- No tilling
		CSR#5 Land use	Land choice	- Marginal, degraded land
				- Fallow land
				- Rotation with traditional cereal
Improve regional development	*Soybean*	CSR#7 Reduce impacts on environment	Crop management	- Mitigation of nitrogen volatilization (N_2O) from soybean straw
	Camelina	CSR#8 Rural development and employment	Animal feed development	- NA

Notes:

No information on critical system requirements on the goals of environmental sustainable biofuels" and "improving region development" provided for palm and jatropha.

Table 20 Sucrose Group.

GOAL	SUCROSE	CRITICAL SYSTEM REQUIREMENT	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Reduce Production Costs	*Sugarcane*	CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs	Plant breeding	- Traditional breeding programs
				- Transgenic
			Logistics	- Pipelines
				- Cost of harvest, collection, and transportation
	Sweet sorghum	CSR#1 Increase feedstock yield and CSR#2 Reduce Feedstock Costs	Plant breeding	- Conventional, MAS breeding
				- Traits - drought/stress tolerance
				- Fertilizers/ripeners
			Crop management	- Fermentation (sugar + starch)
			Industrial processing	- Cellulosic hydrolysis
	Cassava	CSR#1 Increase feedstock yield	Plant breeding	- Varieties for the production of biomass
		CSR#2 Reduce Feedstock Costs	Crop management	- More efficient production systems
				- Mechanization
				- Development and implementation of drying technologies inside the property
			Residue and by-products	- Development and use of by-products and residue use
Environmental Sustainable biofuels	*Sugarcane*	CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha	Plant breeding	- Traditional breeding programs
				- Mechanization of harvest
			Crop management	- Biological pest control
				- Residue use

Table 20 Sucrose Group (continued).

GOAL	SUCROSE	CRITICAL SYSTEM REQUIREMENT	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Environmental Sustainable biofuels	*Sugarcane*	CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha	Crop management	- Soil management and farm practices
	Sweet sorghum	CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha and CSR#4 Energy balance	Plant breeding	- Conventional breeding, MAS
			Crop management	- Minimum tillage
				- Mechanical harvest
	Cassava	CSR#6 Agrochemical use	Crop management	- Biological control (almost no use of agrochemicals)
		CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha	Plant breeding	- Genetic resources for all biotic and abiotic stresses
			Crop management	- Low consumption of nitrogen
Improve regional development	*Sugarcane*	CSR#8 Rural development and employment	NA	- Formal contracts
				- Number of employees sector
				- Monthly earning in the sector
				- Schooling
	Sweet sorghum	CSR#8 Rural development and employment	Plant breeding	- Non sugarcane feedstock suppliers
				- Non sugarcane ethanol producers (microdistilleries)
			Crop management	- Safrinha sweet sorghum producers
	Cassava	CSR#8 Rural development	NA	- NA

Table 21 Cellulosic Group.

GOAL	CELLULOSE	CRITICAL SYSTEM REQUIREMENT	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Reduce Production Costs	Eucalyptus	CSR#1 Increase feedstock yield	Plant breeding	- Hybridization and cloning
				- Improvements of species for resistance to diseases and pests
				- Adaptation of species for areas with water or frost stress
				- Transgenic technologies
			Crop management	- Mechanization and automation of silvicultural practices and harvesting
	Grasses	CSR#1 Increase feedstock yield	Plant breeding	- Selection of elephant grass genotypes of high productivity and quality to be used as alternative energy source
Environmental Sustainable biofuels	Eucalyptus	CSR#7 Reduce impacts on environment	Crop management	- Improve efficiency of water use
				- Maintain or increase biodiversity in the landscape
				- Reduce soil erosion
				- Maintain or increase the nutrient stock in the ecosystem
	Grasses	CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha	Crop management	- Biological fixation of nitrogen
				- Reduce the emission of carbon

Notes:
No information on critical system requirements for Paulownia. No information on critical system requirements on the goal of “improving region development” provided for any of the cellulosic feedstocks.

Table 22 Wastes Group.

GOAL	WASTES	CRITICAL SYSTEM REQUIREMENT	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS
Reduce Production Costs	Municipal Solid Waste	CSR#2 Reduce feedstock costs (Collection costs)	Logistics	- Maximize waste volume for each collection truck
				- Reduce transportation time and distance for the collection
				- Use fuel efficient vehicles
			Collection vehicle	- Decrease labor required for pick-up
Environmental Sustainable biofuels	Municipal Solid Waste	CSR#3 Reduce GHG emissions/ Potential CO_2 net reduction per ha	Landfill Emissions	- Decrease methane emissions in landfill by diverting biogenic MSW to Terrabon process
				- Optimization of truck hauls for feedstock supply and product
			Plant design	- Incorporate new technologies for energy recovery
				- Improve Fuel Carbon Intensity of biofuel
Improve regional development	Municipal Solid Waste	CSR#8 Rural development and employment	Biofuel Plant	- Engineering jobs
				- Management and operation jobs
				- Construction jobs
				- Hauling jobs
			Food waste collection	- Contaminant separation jobs

Note:
No information on critical system requirements for other feedstocks in waste group.

The information on targets to be attained in 2020 and 2050 was only provided in the minority of cases and, therefore, will be addressed in the text rather than listed in **Table 19**, **Table 20**, **Table 21** and **Table 22**. In the oils group, specifically for soybean (regarding the goal to reduce production costs), the targets for 2020 and 2050 from genetic improvement to develop drought and rust tolerant traits was set at 5% and 25% respectively for both critical system requirements (increase feedstock yield and reduce feedstock costs). This means that costs would be reduced by 5% and 25%, respectively, in 2020 and 2050 with plant breeding and productivity would increase by 5% and 25% respectively in the same years with plant breeding. It should be noticed that yield increases with current technology are possible (**Table 16**). The same applied for a variety of cultivated feedstocks. On the goal of environmental sustainable biofuels, specifically for soybeans, the use of biodiesel by machinery is targeted to reduce potential CO_2 net emission per ha in 5% by 2020.

For jatropha, also in the oils group, genetic improvement/breeding for superior genotype selection and disease control was expected to increase feedstock yields by 100% and 50%, respectively, in 2020. Crop management, specifically through fertilization, spacing, growth regulators, pruning, and phenology management was also said to increase feedstock yield in 2020, where: spacing (40%); growth regulators (400%); pruning (40%), and phenology management (100%).

In the sucrose group, specifically for sugarcane, plant breeding (through traditional breeding programs and transgenic varieties) is expected to increase feedstock yield by 25% by 2020. In the case of sweet sorghum, plant breeding through conventional breeding and drought and stress tolerant traits is expected to increase feedstock yields by 100% and 20%, respectively, by 2020. Also for sweet sorghum, crop management through fertilizers/ripeners is expected to increase feedstock yield by 20% by 2020. Still for sweet sorghum, industrial processing through fermentation (sugar+starch) and cellulosic hydrolysis) is expected to increase yields by 50% and 100%, respectively, by 2020. In terms of cost reduction, plant breeding in sweet sorghum through conventional breeding and drought and stress tolerant traits is expected to reduce costs by 40% and 10%, respectively, by 2020. Minimum tillage and harvesting (crop management) in sweet sorghum production are expected to reduce costs by 10% and 30%, respectively.

No targets were established for the other feedstocks in the sucrose group. Also, no targets were established for the cellulosic group. In the waste group, specifically for municipal solid waste (MSW), reducing transportation time and distance for collection was targeted to reduce collection costs by 2% by 2020 and by 3% by 2050. Also, decreasing labor required for pick-up (through changing collection vehicles) would also reduce collection costs by 2% by 2020 and 5% by 2050. Still regarding MSW, improving fuel carbon intensity of biofuel would reduce landfill potential emissions by 2% in 2020 and by 5% in 2050. Furthermore, in plant design, incorporating new technologies for energy recovery would reduce potential GHG emissions by 4% in 2020 and 6% in 2050. Lastly, with regard to the rural development goal, food waste collection, through separation jobs, would improve rural development by 5% in 2020 and 10% in 2050. Construction jobs in biofuel plants would also increase development by 2% in 2020 and 4% in 2050 and management and operation jobs by 5% in 2020 and 15% in 2050.

7.2 Refining Technologies

Table 23 Technology drivers for pretreatment of biomass technologies.

DRIVERS	TODAY (*1 refers to current condition*)	2020 (*numbers reflect relative progress from current condition*)	2030-2050 (*numbers reflect relative progress from current condition*)
1. Pyrolysis			
requires lower cost of equipment	*High losses* (1), *high costs*	0.8	0.7
requires development of larger plants	(1), *high costs*	0.8	0.6
requires higher robustness to low density biomass	*High losses* (1), *high costs*	0.9	0.8
2. Steam explosion			
requires better design of equipment for large scale	High cost (1), needs equipment for scaling-up	0.9	0.8
requires high pressure vapour	High cost (1)	0.9	0.8
better controlled process conditions	High cost (1) of investment	0.8	0.7

Table 24 Technology drivers for conversion technologies.

DRIVERS	TODAY (*1 refers to current condition*)	2020 (*numbers reflect relative progress from current condition*)	2030-2050 (*numbers reflect relative progress from current condition*)
1. Hydrolysis			
requires more selective specific and robust enzymes	*Long times required* (1), *high costs*	0.8	0.7
cheaper enzymes	*Large doses, required* (1), *high costs*	0.8	0.6
faster enzymes	*Large doses, required* (1), *high costs*	0.8	0.6
requires more homogeneous biomasses	Expensive (1)	0.9	0.8
needs cheaper and more efficient enzymes.	Expensive (1)	0.8	0.6

Table 24 Technology drivers for conversion technologies (continued).

DRIVERS	TODAY *(1 refers to current condition)*	2020 *(numbers reflect relative progress from current condition)*	2030-2050 *(numbers reflect relative progress from current condition)*
2. Liquefaction			
requires more systematic studies of solvent mixtures.	Intermediate (1)	0.8	0.6
requires recycling of the solvents and catalytic up grading of the products.	Intermediate (1)	0.8	0.6
3. Gasification			
requires high efficient pressure equipment	Expensive cost (1)	Reduction to 0.5	Reduction to 0.25
requires efficient catalysts for conversion to synthesis gas	High losses (1), high costs	0.8	0.5
needs better equipment efficiency for wet biomass	High losses (1), high costs	0.9	0.7
4. Fast pyrolysis			
requires scale-up of existing pilot plants.	Medium cost (1), efficient	0.8	0.6
requires optimization of pyrolysis conditions to produce high yields of bio-oil.	Needs systematic study (1)	0.8	0.6
5. Fermentation to alcohols			
better yields	High cost (1)	0.8	0.8
lower CO_2 emission	High CO_2 emission (1)	0.8	0.8
fermentation to alcohols or precursors using solid municipal waste			
Requires efficient separation / fractionation (Residues and wastes collection: in the site where the residue is produced and the transportation of the residue to the industrial facility.)	needs to be developed (1)	0.5	0.2
fermentation using municipal waste requires more specific conversion process for each fraction	needs to be developed (1)	0.5	0.3
fermentation using industrial residues	More technology required, more investment (1)	0.6	0.3

Table 24 Technology drivers for conversion technologies (continued).

DRIVERS	TODAY (*1 refers to current condition*)	2020 (*numbers reflect relative progress from current condition*)	2030-2050 (*numbers reflect relative progress from current condition*)
fermentation to alcohols/precursors using flue gases	More technology required, more investment (1)	0.6	0.4
fermentation to alcohols/precursors using sewage	More technology required, more investment (1)	0.6	0.3
6. Fermentation to lipids			
requires higher conversion of sugars and higher yields to lipids	More technology required, more investment (1)	0.7	0.5
requires faster microbial metabolism & higher productivities	More technology required, more investment (1)	0.7	0.5
requires more robust yeasts/microalgae to be used in an industrial scale	More technology required, more investment (1)	0.8	0.7
requires cheaper feedstock as lignocellulose and wastes.	More technology required, more investment (1)	0.8	0.6

Table 25 Technology drivers for jet fuel production technologies.

DRIVERS	TODAY (*1 refers to current condition*)	2020 (*numbers reflect relative progress from current condition*)	2030-2050 (*numbers reflect relative progress from current condition*)
1. HEFA			
requires cheaper microbial oils	more investment (1)	0.8	0.6
requires extraction and pretreatment of oil	More technology required, more investment (1)	0.8	0.6
requires standardization of feedstock.	More technology required, more investment (1)	0.8	0.6
Requires cheaper hydrogen	Cheaper/ more abundant hydrogen sources		

Table 25 Technology drivers for jet fuel production technologies (continued).

DRIVERS	TODAY (*1 refers to current condition*)	2020 (*numbers reflect relative progress from current condition*)	2030-2050 (*numbers reflect relative progress from current condition*)
2. Alcohol to jet fuel			
requires more selective catalysts which would convert the alcohols more efficiently to jet fuels.	More technology required, more investment (1)	0.8	0.5
Requires better industrial plants.	Less operation steps, too expensive (1)	0.8	0.4
Requires simpler technology.	Too complicated (1)	0.7	0.5
Requires higher yields	Low yield (1)	0.8	0.7
3. Fischer Tropsch			
Requires efficient high pressure equipment.	Too high pressure required, expensive (1)	0.8	0.6
Requires efficient catalysts.	Better catalysts needed, expensive (1)	0.8	0.7
Requires large amounts of biomass to optimize the costs.	Requires more concentrated/ dense feedstock	0.9	0.8
4. Direct sugars to hydrocarbon (DSHC)			
Requires better use of sugars (less by-products).	Low conversion, low yields, too expensive (1)	0.9	0.7
Requires standard sterilization equipment for genetically modified microorganism.	Easier contamination than bioethanol, standard sterilization protocol is required, more expensive (1)	0.8	0.5
5. Bio-oil upgrading			
Requires cheaper catalysts.	Expensive catalysts used (1)	0.7	0.5
Requires hydrogen transfer from cheap sources.	Molecular hydrogen used (1)	0.7	0.5

8 CURRENT SCIENTIFIC AND TECHNOLOGICAL CAPABILITIES

8.1 Feedstock

The success of Brazilian agriculture is not just a matter of land availability and good climatic conditions. Brazil has a tradition in public agriculture research and education centers that have paved the way to its success. In the past 50 years the Brazilian government, both at federal and state levels created new research institutions and promoted R&D in an expanding university system. At the same time, the dynamism and opportunities of Brazilian agriculture have attracted private companies and cooperatives to develop technology in agriculture related fields.

Many public institutions have R&D activities in multiple areas. This is the case of Embrapa, the Federal agriculture research institution with 48 research units throughout Brazil. Embrapa has research centers dedicated to crops or themes directly related with bioenergy: Agroenergy Center, Soyben Center, Forest Research Center, Cassava Center.

APTA – The São Paulo State Agency of Technology of the Agrobusiness has a model similar to that of Embrapa, but in a smaller scale and at the state level. Some of its institutes such as the Agronomic Institute of Campinas (IAC), Biological Institute (IB) and Animal Science Institute (IZ) do research in topics of bioenergy. IAC Sugarcane Center has a sugarcane breeding program since 1933. Other states have also similar institutions such as IAPAR, Goiás Rural Agency, EPAMIG, Empaer MT, among others.

Currently there are 80 graduate programs offering M.Sc. and or Ph.D. level degrees in areas of agricultural sciences with some research activity. Of those, many have a long standing tradition in agricultural research such as ESALQ-USP, CENA, UNESP, UNICAMP, USFCAR, IAC (in the state of São Paulo), UFLA, UFV and UFU (Minas Gerais), UFRGS, UFSM, UFPE (Rio Grande do Sul), UFPR, UEL (Paraná), UFRRJ (Rio de Janeiro), UFSC and UDESC (Santa Catarina), UFRPE (Pernambuco), UFBA, UFRB (Bahia) and several other new graduate programs.

Several institutions develop sugarcane varieties in Brazil, which make possible the availability of a large number of varieties, adapted to the different regions and soil types. Among the public institutions are IAC, already mentioned, and RIDESA (Interuniversity Network of Sugarcane Plant breeding Program) which is the present leader of varieties in Brazil and started to breed sugarcane in 1972. Embrapa is a newcomer in the field but has good infrastructure to progress rapidly. CTC (Sugarcane Technology Center) is the oldest of the private institutions, funded by the sugarcane business sector, which started it program in 1968. Several international companies started to develop sugarcane varieties in Brazil: Monsanto (Canavialis), Syngenta and BASF.

Soybean varieties were initially developed by public institutions such as IAC, Embrapa, IAPAR, EMGOPA, EPAMIG and some university departments, but, more recently there are more than ten soybean seed companies, many of them international, which are competing in the market, bringing new technologies and expertise: Pioneer, Monsanto, Nidera, Syngenta, and many Brazilian private companies such as Coodetec, TMG, Brasmax, Adriana, Agroeste and others.

Seeds for biofuel crops are being tested in Brazil by international companies such as SGB (Seeds Genomics Biofuels) from San Diego, USA, which develops jatropha hybrids, and the Camelina Company (Spain, USA) which is adapting camelina varieties to Brazilian conditions.

Public institutions such as Embrapa, IAPAR and IAC have breeding programs for hundreds of plant species, including grasses for pasture; some of the private companies also develop hybrids and varieties for other crops, but usually those of higher market value such as maize, soybean, cotton, sunflower, etc.

Plant breeding was pointed out as key for improving biofuel crops, decreasing feedstock prices, and solving specific problems of crops in the short and long term. It is clear that Brazil has a very good R&D infrastructure for developing or adapting new varieties and hybrids for biofuel crops.

Other R&D topics are also important for jet biofuel. The main institutions working on the subject in Brazil are listed in **Table 26**.

Table 26 Public and private organizations involved in R&D for biofuel feedstocks in Brazil.

FEEDSTOCK	ORGANIZATIONS
Sugarcane	IAC
	CTC
	RIDESA
	Embrapa
	Universities in general
	CTBE – Brazilian Bioethanol Science and Technology Laboratory
Sorghum	CERES
	Embrapa
	IAC
	IAPAR
Cassava	IAC
	Embrapa
	IAPAR
	EPAGRI
	Consolidated breeding programs (IAC, EMBRAPA, IAPAR)
Soybean	Embrapa
	IAC
	Universities (ESALQ, Federal University of Viçosa, Federal University of Rio Grande do Sul)

Table 26 Public and private organizations involved in R&D for biofuel feedstocks in Brazil (continued).

FEEDSTOCK	ORGANIZATIONS
Palm and Jatropha	SGB
	Embrapa Agroenergy
	IAC
	IAPAR
Camelina	Camelina Company (Brazil, Spain, USA)
Eucalyptus	Universities (ESALQ, UNESP, Federal University of Viçosa, Federal University of Parana, Federal University of Lavras, Federal University of Santa Maria, among others)
	SIF – Society of Forest Investigation
	FUPEF – Forest Research Foundation of Parana
	Embrapa – Forest Center
	Rede de Pesquisas em Florestas Energéticas no Plano Nacional de Agroenergia
Grasses	Embrapa
	IZ
Municipal Solid Waste	Brazil: CENBIO - Brazilian Reference Center on Biomass

8.2 Refining Technologies

There is less technological capability on refining technology in Brazil than on feedstocks and agriculture. The best potential capability for jet biofuel in Brazil is related to large scale fermentation of sugarcane to bioethanol and hydrocracking of vegetable oils (HBio/Petrobras). However, in other countries, the technological capabilities are more advanced, as shown by the different presenters in the workshops. Branches of international companies such as Amyris, Solazyme, Novozymes and others, are working with Brazilian private companies to develop or adapt feedstock processing technologies.

Embrapa (Brazilian Agriculture Research Corporation) is one of the most important research institutions on agribusiness, including many specialized branches for different products/technologies and regions. In addition, there are other relevant research centers and groups, such as universities and public and private organizations with tradition in agriculture research and related technologies.

Sugarcane and Sorghum refining technology is developed mostly at CTBE Laboratório Nacional de Ciência e Tecnologia do Bioetanol, CTC Centro Tecnologia Canavieira. The State and Federal Universities (UNICAMP, USP, UNESP, UFSCAR, UFV, UFRJ and others) also are very important actors on the generation and advances on refining technologies, where the advances are mostly done at the Food Engineering, Chemical Engineering, Agriculture Engineering, Mechanical Engineering schools and at Institutes of Biology and Chemistry).

Technology for eucalyptus is also investigated in universities (ESALQ, UNESP, UFV, UFPR, UFL),and research centers such as Fundação de Pesquisas Florestais do Paraná (FUPEF), EMBRAPA – Centro de Florestas, Rede de Pesquisas em Florestas Energeticas no Plano Nacional de Agroenergia, and Instituto de Pesquisas Tecnológicas de São Paulo (IPT).

The current implementation of commercial plants to produce cellulosic biofuels is not fully implemented worldwide, including in Brazil. However, several second and third generation technologies for biofuel production seem to start to go into commercial scale, although many previously announced such initiatives failed to materialize (THE ECONOMIST, 2013).

Solazyme has recently announced two plants to produce oils from sugar, through algae fermentation, one in the USA and one in Brazil. In the USA, Solazyme intends to produce 20,000 t/yr of oil from dextrose in a joint project with Archer-Daniels-Midland (ADM), primarily for the industry and food markets (SOLAZYME, 2013).

In Brazil, at Usina Moema, in São Paulo State, Solazyme lauched a project for 100,000 t/yr production of oils from sugarcane for the Brazilian industry and fuel market, starting in late 2013, in a joint venture with Bunge Limited (SOLAZYME, 2013).

GranBio, a Brazilian company, has started building a second generation ethanol plant in Alagoas, in the Northeastern sugarcane region, with a nominal capacity of 82 ML of ethanol from sugarcane bagasse and trash. Steam explosion technology of the Italian company Chemtex, enzymes from Novozymes and yeast from ADM will be used there. The plant is expected to start operating in 2013 (GRAALBIO, 2012).

Amyris has launched a plant to produce farnasene at Usina Paraíso, Brotas – SP with six reactors with 200,000 liters capacity each.

These Brazilian initiatives are supported by funds from BNDES, the Brazilian National Development Bank. If successful, the outcomes of such biofuel businesses may represent a new stimulus to an industry plagued with projects postponed or canceled, and have a positive effect on sustainable jet fuel research, development and deployment.

9 GAPS AND BARRIERS

9.1 Feedstock

9.9.1 Biomass cultivation

A multicriteria analysis conducted on the 2nd Workshop ("Feedstock") looked at feedstocks according to three broad categories: (i) strategic potential, (ii) technical risks and (iii) commercial risks. That analysis showed that all categories of feedstock alternatives have strategic potential to be compliant with the roadmap goals, but technical and commercial risks need mitigation and are somewhat specific to each feedstock being considered; therefore only the categories (ii) and (iii) are detailed in **Table 27**.

Table 27 Pros and cons of feedstock alternatives.

FEEDSTOCK GROUP	TECHNICAL ASPECTS		COMMERCIAL/FINANCIAL ASPECTS	
	PROS	CONS	PROS	CONS
Sucrose/ starch	• High energy yields • Production systems know-how • Integration (sugarcane and sorghum) • Accumulated scientific knowledge in agriculture and refining technologies	• Need to improve technology adoption (cassava) • Low level of mechanization (more relevant in cassava) • Expansion in new areas increase • Competition with other uses (all feedstock)	• High availability • Well organized supply chains (especially sugarcane) • Potential to promote strong social outcomes (cassava) • Commercial co-products (bagasse, fiber cake and trash)	• High opportunity cost of the sugarcane (sugar and ethanol markets) and bagasse (energy generation) • Land/food security concerns (cassava) • Long term economic activity: requires stable policies to promote investments • Logistics (short shelf life)
Oil-bearing	• High energy yields (palm, algae) • Potential to be a second crop and/or cultivation in marginal areas (camelina, jatropha, peanut)	• Lower energy yields (except palm) • Competition with food (except camelina, jatropha and algae)	• Well organized supply chains (soybeans) • High availability (soybean and potentially native palm trees)	• Related to food chain (soybeans, palm and sunflower) • A large number of the feedstock alternatives in this group is not produced in scale in Brazil

Table 27 Pros and cons of feedstock alternatives (continued).

FEEDSTOCK GROUP	TECHNICAL ASPECTS		COMMERCIAL/FINANCIAL ASPECTS	
	PROS	CONS	PROS	CONS
Oil-bearing	• Sufficient know-how (soybean) • Good storability	• No available seeds or agricultural technologies (camelina, jatropha, native palm trees and algae) • Logistic (low yielding oil crops)	• Commercial co-products (soybean, palm, sunflower) • Logistic (grains can be stored and easily transported)	• Land/food security concerns • No policies to stimulate production in place (camelina and jatropha) • Logistic (palm): production in Amazon and short shelf life
Cellulosic	• High yields (wood, cane, grasses) • Located in the industrial site (bagasse, forestry residues) • Multiple uses (electricity, fuel, etc.) • Co-products • Suitable for hilly soils • Low use of agrochemicals (fertilizer) per unit biomass produced (wood) • Good storability (wood) • Long (& flexible) harvesting season (wood)	• Efficient refining technologies not developed • Relevant opportunity cost: bagasse, forest products • High demand for N - sustainability (grasses)	• Out of the food chain • Low opportunity costs (co-products) • High availability	• Collection costs (agricultural residues) • High costs to store (grasses)
Wastes	• High energy balance (no energy used for production) • Large supply (cities are main destination of agricultural products)	• Refining technologies are maturing (flue gas, MSW, sewage) • Variable composition (difficulty for refining) • Logistic (used cooking oil)	• Low cost feedstock • Large volumes available now • Out of the food chain • No indirect land use change • Low opportunity costs	• High collection, separation and preparation costs (MSW, used cooking oil, sewage) • Need to build a supply chain

Table 27 Pros and cons of feedstock alternatives (continued).

FEEDSTOCK GROUP	TECHNICAL ASPECTS		COMMERCIAL/FINANCIAL ASPECTS	
	PROS	CONS	PROS	CONS
Wastes	• Positive environmental impact		• Industrial waste is point sourced	• Bureaucratic legislation to obtain environmental permits (MSW) • High cost & other uses (tallow)
General	• Land and water availability, favorable climate • Agriculture know-how	• Competition for land • Irregular (hilly) landscape (annual and row crops)	• Improve rural development • Cost competitive	• Limitation for small farmers (scale or production) • Affected directly and indirectly by food price (and agrochemicals, land)

9.1.1.1 Group 1: Sucrose/Starch

Examples of crops/raw materials with sucrose/starch: Sugarcane, Sorghum, Cassava.

Gaps

Brazil has good infra-structure for R&D on the main feedstocks of the sucrose/starch group because these are already produced in relatively large scale. In the case of sugarcane, more than 8 million hectares are grown with this crop, half of it to produce biofuel. Several research centers in Brazil do research on the various aspects of this feedstock production chain; therefore, implementing new or adaptive research for aviation should not be a problem. In a certain way, the research that is needed to expand present sugarcane first generation biofuel can also apply for the aviation biofuel requirements. Improve feedstock production and lower their costs are important tasks, although sugarcane is already a competitive source of plant material. Among the important issues are the agronomic research focused on incremental gains: plant breeding to create varieties that are adapted to different soil and climate conditions, that have improved drought tolerance (expansion of sugarcane toward central part of Brazil), that are resistant to traditional and new diseases (disease resistance is often broken with time; new diseases and pests are always a risk as it is the case of the orange rust, recently introduced in Brazil), that have upright architecture to make possible mechanical harvest, and that can sprout easily under trash mulch (green cane harvest), amongst other traits. Research on improved agronomic management is needed also to increase yields and longevity of the crop, increase nutrient use efficiency, prevent or decrease soil compaction, and control weed and pest using less agrochemicals. In this sense, precision agriculture is an area of great interest. Research on machines and equipment should focus on increasing harvesting efficiency, producing a feedstock that is less prone to deterioration in a short time, and decrease the damage to the plant stools so that ratoon yields may not decline rapidly.

Sustainability is a key aspect for feedstock production. Research should focus on increasing nutrient use efficiency, particularly of nitrogen (N), on strategies for nutrient cycling, on assessment of carbon dioxide emissions under field conditions and on the carbon (C) balance of the crop, in special on practices that maintain or increase soil C stock. Of particular interest is the assessment of factors that may influence the decision of how much plant material should be left on the soil after harvest in order to maintain soil quality in the long term, vis-à-vis the need of collecting residues for biofuel production.

Current low production and yields of sugarcane in Brazil indicate the need of new varieties and actions to expand production are additional gaps (**Table 28**).

Most of these research lines also apply to other agricultural feedstock, although certain peculiarities must be taken into account. For instance, sorghum, especially sweet sorghum, has a much smaller research base in Brazil; the germplasm is much more restricted and agronomic practices much less developed. Of particular interest is the research to expand the harvesting season, through the development of new varieties. In the agronomic front, sorghum, as a grass, may not be a good rotation crop for sugarcane, especially if repeated rotation cycles are considered. Therefore, options of other crops to include in the rotation are important, having in mind that one of the attractive points of sorghum is that it is processed along with sugarcane and, ideally, it should be grown near the mill.

Research on cassava is not as developed in Brazil as that for sugarcane, but, still, considerable knowledge exists. Research should focus on obtaining new varieties, adapted to different soil conditions and with a wide range of harvesting time – already an advantage of this crop. Besides the research lines highlighted for sugarcane, cassava research should focus on the relatively low amounts of plant residues left after roots are harvested, a limitation both to replenish soil C and as source of energy for feedstock processing and biofuel production.

Additional gaps, related to the lack of tradition of using cassava starch to produce biofuels and the difficulties of mechanized harvest were also pointed out in the experts panel (**Table 28**).

9.1.1.2 Group 2: Oil bearing feedstock

Examples of oil bearing crops/raw materials: soybean, palm, jatropha, camelina, sunflower, peanut, other palm trees, photosynthetic algae.

Gaps

Soybean is also a crop with a large acreage and research base in Brazil, which explains why it is the main feedstock for biodiesel. It is grown practically in all latitudes thanks to intense work of plant breeding done by many institutions in this country. Therefore, the infra-structure is in place, ready to deliver further improvements for this crop. Soybean has a relatively small oil content compared to several other oil crops: breeding to improve oil content is of interest, although the fact that this crop is a good source of protein is an advantage for its multiple uses, a positive aspect for farmers that produce the feedstock (**Table 28**). The short harvesting season is not a problem because of the storability of this grain.

Food security may be an issue in international forums with soybeans and other oil crops such as peanuts and sunflower. However, due to large land availability in Brazil, food security was not placed in high priority in the present document, as discussed earlier. In addition, the processing of oil crops for biofuel leaves high protein meals that can be used as animal or human food.

Research infrastructure of sunflower, peanuts, and castor bean in Brazil is much smaller than that of sugarcane or soybean. Breeding and agronomic research can also improve yield and the potential of these crops to serve as biofuel feedstock; however, these crops have competing uses as food or as source of highly priced oils and may not fit the required low-price characteristic of the ideal biofuel feedstock. However, the marked for biofuel production may be an interesting alternative for farmers to deal with overproduction or to sell grains not suitable for food; therefore such crops may be occasionally used for biofuel production because the transformation technology for oil crops probably will allow different seeds to be processed.

Camelina, in a sense, will have the same limitation of sunflower and peanuts, with the disadvantage of having a much lower germplasm and research base. It may be an option for some markets if the agronomic research challenges are overcome. Other gaps and barriers are listed in **Table 28**.

Jatropha has potential to supply oil for biofuel and has an advantage of not competing in the food market. However, research is needed mostly in plant breeding, selection of uniform plant material, and adaptation to different soil and climate conditions. The research base in Brazil is relatively poor so far, and jatropha may require a greater research effort and long maturation time. However, efforts by newcomers into the Brazilian scene, such as SGB, and by Embrapa, IAC, and other research institutions in Brazil may speed up progress, as discussed in section II.1.1. Harvest mechanization is a topic of interest for jatropha because the plant architecture is much different from that of other oil seeds. Seed production spread through a long period is a problem for mechanical harvesting; therefore, besides machine development, the jatropha plant should also be altered through genetic improvement or management practices such as pruning, use of plant growth regulators etc. (**Table 28**).

Palm is the most productive oil crop. Expanding its production area is a barrier because of the high water requirement of present varieties (today it is suitable only for very wet and hot climates). The research base is limited in Brazil. Research on sustainability issues such as soil C degradation, nutrient cycling, CO_2 and other GHGs emission in the cropping production system, and others are important to turn palm into a viable feedstock for biofuel in Brazil, especially considering that the best areas for production are in wet forests (**Table 28**).

Other native palm trees, as discussed in the workshops, seem to have potential, but the research base is poor. The pathway to developed technology for large scale plantations of such palm trees is known – the same breeding and agronomic research used to create and adapt other crops, as done with several other plants in Brazil and elsewhere - but results are of long term and uncertain. The biofuel industry probably cannot count on this type of feedstock within the next 20 or more years.

Photosynthetic algae is always mentioned as the oil feedstock with the largest yield potential but most of such high production has been obtained under controlled conditions. Much research is still needed to turn algae into a commercial option, especially due their high nutrient, light and temperature requirement. Harvesting is also a problem to be solved. Sustainable algae production in large scale is a project for the long run.

9.1.1.3 Group 3: Lignocellulosic feedstock

Examples of crops/raw materials with lignocellulosic feedstocks: forest wood residues & wood, sugarcane bagasse and harvest residues,iIndustrial forest residues (pulp, sawdust, bark), agricultural residues (straw, grasses), dedicated plants such as forages.

Gaps

If and when converting technology problems for lignocellulosic materials are solved[11], the options of forest-derived feedstocks in Brazil are excellent. Brazil is one of the largest and most efficient producers of planted forests; therefore, a very good research base is available, especially for eucalyptus. Climatic conditions are favorable in most of the country. An additional advantage of planted forest feedstock is that it can be produced in areas with irregular topography, which limits annual or row crops production. The feedstock can be stored for long periods and the harvesting season is long and flexible. Nutrient cycling usually is not a limiting factor for sustainability since most of the harvested parts have low nutrient content. The agronomic research should focus on further adaptation of plant materials for marginal lands (low fertility, relative dry areas), agronomic management for high yield, and practices that minimize soil compaction and degradation due to the operation with large harvesting machines (**Table 28**).

Planted forests are already widely used in Brazil to produce energy for the iron industry. However, it is likely the price competition will limit the use of forest logs for biofuel production, but the large demand for wood, paper and other forest products may increase the supply of forest by-products which can be processed for energy: pulp, sawdust, bark, and other wood residues.

Most of the research on sugarcane residue (bagasse and harvest residues) production was listed under sucrose feedstock. However, specific research applies for sugarcane lignocellulosic feedstock: this is the case plant breeding for the so-called energy cane, in which lignocellulosic material is favored instead of sugars. Sugarcane breeding programs have long been improving sugar concentration in stems and sugar yield. Now plant breeding research may have to go back to other sugarcane germplasm in order to obtain plants with high cellulose content. However, the source of such genes is known so that it may be feasible to have an energy cane in a relatively short period of time.

Nutrient cycling, criteria for decision of how much residue to leave on the field, water use and other topics related to sustainability also need research efforts.

For other crop residues (corn, cotton, rice, wheat) the most relevant research topic for their use as feedstock for biofuel production regards collection and transport, nutrient cycling, soil C balance, and soil fertility maintenance.

Tropical grasses used as forage, especially, Guinea grass (**Panicum maximum**) and Elephant grass (*Pennisetum purpureum*), have huge potential to produce cellulosic material. However, high yields usually require large nutrient inputs, which raise questions about sustainability and nutrient cycling. These are topics of interest for research with such

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[11] A commercial plant to produce second generation ethanol was planned to operate in a commercial scale in Brazil in 2013 (GRAALBIO, 2012), now 2014 (See also section II.5.2).

grasses. Plant breeding is an alternative to increase nutrient use efficiency and generate varieties more suitable for biofuel production. In addition, harvesting practices and equipment, and storability deserves attention (**Table 28**).

9.1.1.4 Group 4: Residues or Wastes

Urban wastes, industrial flue gases, tallow and used cooking oil are options for biofuel production, not only to recycle products that would otherwise require costly disposal, but also because they avoid the food vs. fuel issue. In the European Union, for a feedstock classified as a residue or a waste, it will be easier for the fuel producer to fulfill the sustainability criteria of the Renewable Energy Directive (RED). Further, there is a double counting mechanism depending on the use of a residue or a waste. As well, in some member states there is a direct link to eligibility for state aid for instance in the form of tax benefits. This makes feed stocks classified as residues or wastes attractive from the fuel producer's perspective.

Gaps

"Wastes" or "residues" are non-desirable products, with no or low-commercial value. The processes or production chains from which the waste materials (solid, liquid or gas) are produced are not discussed here.

The potential for biofuel production from municipal solid waste and agricultural wastes is enormous because most of the agricultural products, be it food, paper, wood, ornamental plants, clothes etc, end up in the urban areas where they are consumed and generate wastes. An Important part of the logistic costs for transportation from the site of production to the cities is covered by the consumer of the original product. An estimated 50% of food produced globally is lost somewhere in the long production chain from the farm to the retail places (Smil, 2000). Theoretically, a sizeable part of the food produced can be recycled and used to generate energy.

Differently from the agriculture feedstocks, the objective is not to produce wastes but rather to make use of them, since they represent an environmental problem that needs to be mitigated such as with carbon dioxide emissions. On the contrary, probably the main R&D objective concerning wastes should be how to avoid their production, since their non-existence represents an important value in itself. The R&D related to wastes should be oriented to:

1. Reduce the generated wastes;
2. Reduce the final disposal costs;
3. Optimize and reduce collection costs;
4. Produce a "more friendly" waste with respect to environment and;
5. Use its remaining potential value, so to exhaust the use of its chemical and energy potential. What is a "waste" in a process can be considered an input in another;
6. Cogeneration (for example, use of a fuel to generate mechanical work and electricity and process heat widely used in all sugar/ethanol mills in Brazil).

Several biofuels programs like the Brazilian sugarcane ethanol, the American corn ethanol, and the European biodiesel try to make a complete use of the raw material to generate no residues or wastes; however even these industries have substantial wastes (gases and energy) with potential to be used.

Even though there are very promising processes to convert the above mentioned residues to jet fuel – such as LanzaTech's process for fermentation of CO rich flue gases, Terrabon's MixAlco® Process for the organic wet fraction of MSW (municipal solid waste), or HEFA (hydrogenation of esters and fatty acids) process to convert used cooking oil or animal fats – the main difficulty is to have the residue available under controlled quality and low cost conditions.

For the case of CO-rich flue gases, the main petroleum refineries in Brazil already have CO boilers that use the flue gases, for instance from catalyst regeneration process, to produce steam that is used in the refineries. Many of the large integrated steel mills also are using their main flows of flue gases to generate power. Probably there are some steel mini-mills that have CO-rich flue gases not yet recovered, but they have to be identified and the available amount quantified.

One possible very efficient process to exploit the energy contained in municipal solid waste (MSW) is to begin with a separation of the dry and wet portions and proceed with separate routes. The dry portion, after recovery of recyclables, can be burned in a boil to produce steam and generate electricity or be gasified to produce liquid fuels through a GTL (gas to liquid) process. The wet organic fraction can be fermented to produce bio-gas (mainly methane and carbon dioxide) that can be used as energy, feedstock for chemical process or even be transformed in liquid hydrocarbons through a GTL (gas to liquid) process. Another possibility is to interrupt the fermentation process inhibiting methanogenesis, therefore avoiding the gas phase to reduce costs, and producing carboxylic salts using the MixAlco® Process, to be discussed in more detail in the next chapter. Important to recall that MSW in Brazil has a large wet organic fraction, rich in food residues that are not permitted to go into sewage, what makes this last process quite appropriate for the Brazilian conditions.

The amount of MSW per capita runs about 1kg/day, which if summed up in the metropolitan areas where the main airports are located, could supply near around 20% of the jet fuel consumed. The main gap here is that nowadays almost the totality of MSW is dumped in landfills without any separation. Although a specific law to deal with solid residues and to pinpoint responsibilities has been recently approved in Brazil, the waste management in this country is in general poor and even worse when referring to MSW. Although some recycling is usual, mainly for paper and cardboard, aluminum cans and glass, and approximately 20% of the produced methane in large landfills is captured to generate electricity, until now, the amount of MSW burned to produce power is negligible, because of a comparatively low dumping cost. Therefore, the main gap to make use of MSW, and also the main opportunity, rests on the improvement of solid waste management as a whole, to be pushed mainly by municipalities.

The utilization of used cooking oil to produce biofuel is determined by the necessary management to make viable a reverse logistics process. Even though some private companies are doing it to produce biodiesel, the total amount nowadays collected in the Brazil for this purpose, if directed to jet biofuel, would respond for less than 0.5% of jet fuel consumption. Certainly that amount could be increased several times, but again, the whole process of education for better residue management, pushed by public policies, is the main gap.

The use of animal fat to produce biofuel is well developed in Brazil due to the biodiesel production program. Presently, the total amount of tallow and other animal fats processed to biodiesel in the whole country, if directed to jet biofuel production, would suffice to 5% of jet fuel consumption. The main gap for this alternative is the final price that, for the biodiesel production condition, runs about adding US$ 0.40 per liter.

The possibilities of using the remaining energy in sewage for producing liquid biofuels is small, because of the very high dilution and Brazilian rules that determines the exclusion of food leftovers in the sewage, in such a way that this alternative was dropped out during the discussions of previous workshops.

The gaps and barriers presented are those identified by the authors of this report based on the ideas discussed in the four previous sections. They are presented both individually per feedstock and grouped when the feedstocks share similar situation (**Table 28**).

Table 28 Main gaps and barriers associated with feedstocks for aviation biofuel.

FEEDSTOCK	GAPS AND BARRIERS
Soybean	- Low oil content, low energy yields and reduced perspective for researches focused on increasing oil content, given that the protein market is still more relevant for soybean producers and crushers. - Although oil and meal do not compete, because they are products of the soy crush, the crop is strongly connected to the food markets. - Food security concerns[12].
Palm	- Although its productive potential is known in Brazil, planted area is still too small. The main gap is to create conditions for the expansion of the planted area. - The increase of the planted area can potentially create agronomic problems and problems with diseases (such as bud rot). A second gap is that it can be expected that production cost will probably be higher in the first years of implementation of plantations. - Deforestation may be an issue because palm requires much water and is best grown in rain forest regions. Food security and deforestation will probably not be a barrier for palm oil as long as plantations are developed in low yield pasture lands. - Food security concerns[13].
Camelina	- The main gap is that the performance of the crop is still not known in Brazil and energy yield, although potentially higher than soybean, is lower than palm. On the other hand, camelina requires N fertilization, which soybeans do not. - Barriers can be overcome if camelina turns out to be an efficient second crop, which still needs to be proved for Brazilian conditions.
Jatropha	- The main gap is that the crop is not commercially available for production because several agronomic problems still need to be solved through research. Mechanical harvest is important to guarantee economical return. - The toxification problem of the jatropha cake is also a gap.

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[12] See discussion about food security in 6.1.1.2.

[13] See discussion about food security in 6.1.1.2.

Table 28 Main gaps and barriers associated with feedstocks for aviation biofuel (continued).

FEEDSTOCK	GAPS AND BARRIERS
Sugarcane	- Sugarcane is facing a short term gap due to supply shortage and lower yields. Sugarcane is not performing yield increases as it used to in the past, which requires larger investments to promote the expansion of the production. Increasing yields is the main gap, also because production costs have increased in the last years. - A barrier for the use of sugarcane in the jet biofuel market is the high opportunity cost of the cane (sugar and ethanol markets) and the bagasse, given that it is largely used for electricity generation. Although being a residue of the cane crushing, the bagasse is not a tip free residue. - Sugarcane expansion is taking place towards regions with longer water deficit periods, low fertility and non-traditional areas, increasing risks and costs. - Food security concerns[14].
Sweet sorghum	- The main gap is to create conditions for the integration of the crop in the sugarcane production chain. The economic rationale of sweet sorghum arises from its integration to sugarcane. - Once integrated to sugarcane, the main gaps are related to plant breeding oriented to increasing yields and to extending the harvesting period. - To develop an industrial process to allow the use of the starch contained in the grain is a gap in the industrialization, specially having in mind that the sorghum is to be processed in sugar mills.
Cassava	- The main gap for cassava is that Brazil has no tradition in producing energy from starch. - Although being a rustic plant and cropped in different regions, examples in Brazil show that the achievement of high yields requires good crop management. - Mechanization is a barrier for allowing the use of cassava as a feedstock for biofuels. - Food security concerns[15].
Eucalyptus	- Similar to sugarcane, expansion is occurring in degraded areas and in areas susceptible to high degrees of water and thermal stresses. Given that it is very difficult to balance in a same genotype biotic resistance, tolerance to drought or frost, good productivity and good quality of wood, it is necessary to produce interspecific hybrids (cross-bi, tri-cross and so on). - Creating the facilities and the infrastructure necessary to allow the use of residues for producing biofuels is also a gap.
Grasses	- The use of grasses to produce energy is something new in Brazil. Grasses have been used for animal feed; management practices such as the use of fertilizers, are not widely adopted. - Cut, collect and dry large amounts of biomass is a barrier. Costs are not known and solutions and machinery are not in the market. - Selection of more productive and efficient genotypes is also a gap.

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[14] See discussion about food security in 6.1.1.2.

[15] See discussion about food security in 6.1.1.2.

Table 28 Main gaps and barriers associated with feedstocks for aviation biofuel (continued).

FEEDSTOCK	GAPS AND BARRIERS
Industrial and Municipal Solid Waste	- Tallow is already widely used to produce biodiesel in Brazil (15% of the non-fossil oil) but the other residues require big efforts to solve collection and or separation problems. - Logistical issues are the key barriers. Feedstock volume required for large scale production facility takes time to develop, because it requires transition from compost or anaerobic digestion to biofuel plant. Biogenic MSW collection costs must be competitive with current costs. - Environmental legislation can potentially be a constraint because the use of solid waste should require different permits.

The gaps and barriers can be aggregated into groups according to feedstock characteristics (**Table 29**).

Table 29 Gaps and barriers for feedstocks with different categories.

GROUPS	EXAMPLES
(i) Feedstock in early stages of research that still need time to be introduced in the market. In these cases, the gap is the lack of technological packages available for farmers:	camelina and jatropha
(ii) Feedstock with high opportunity cost:	sugarcane, palm and eucalyptus
(iii) Feedstocks for which the production costs are high due mainly to logistics costs:	grasses and municipal solid waste
(iv) Feedstock for which food security is an issues because of the importance of the feedstock for the food market:	soybean and cassava
(v) Feedstock viable only if integrated to production systems:	sweet sorghum and camelina

9.1.2 Feedstock logistics

Transportation infrastructure is considered a major bottleneck for transporting commodities in Brazil. The country large territory, high population concentration along the coast and lack of capital are probably the main reasons. Major agricultural crops such as soybean, sugarcane and products from planted forest have difficulties to reach final markets. Off course this lack of infrastructure greatly affects product costs and may represent an obstacle to the interiorization of feedstock production for biofuels production in Brazil.

Other risks are associated with harvesting during the rainy season (December to March) resulting the need to encounter another solution (store the feedstock or the final product). Finally, introduction of ICT technology can greatly contribute to improve feedstocks logistics (Information and Communication Technologies as GPS, GIS, softwares to optimize the fleet, etc.)

9.1.3 Gaps and impacts from sustainability requirements

The 4th workshop was divided in sections according to the three pillars of sustainability (economic, social and environment), as well as a section focused on the sustainability standards. The sections on the sustainability pillars had three speakers, being one from academia, one from the productive sector and another one from an NGO.

On the second day the stakeholders were divided into four groups, according to the feedstock groups – Sucrose, Oil, Waste and Lignocellulosics. Each group discussed and filled out a spreadsheet in order to identify, for each sustainability requirement, the compliance gaps and the impact of the sustainability requirement on the following dimensions: Technical (related to the production process), Financial (related to the monetary resources required) and Commercial (related to market issues). The assessment of the impact of the sustainability requirements on the three dimensions was necessary because they were also part of the discussions of the workshops on feedstocks and refining technologies. The three dimensions, therefore, although apparently not related to sustainability, create channels of communication among the three workshops.

The stakeholders were asked to give their opinion regarding compliance gap and the requirement impact on the afore mentioned dimension.

The Sustainability requirements analyzed were:

(i) Laws and International Conventions

Compliance with relevant national laws and international conventions;

(ii) Land Rights

Having official documents to prove title to land or right to use land

(iii) Employment, Wages and Labor Conditions

Compliance with laws and regulations related to wages, working hours, breaks, overtime and formal contracts. Rights to organize, complaints and communication mechanisms (labor unions, etc.);

(iv) Human Health and Safety

Comply with regulations and standards of conditions of occupational safety and health for workers (Example: NR-31);

(v) Carbon dioxide emissions

Emissions reduction potential and calculations. Different requirements for each standard;

(vi) Biodiversity and Ecosystems

No negative impacts on biodiversity and ecosystems

(vii) Soil

Soil conservation, maintaining soil health and reversing soil degradation (example: erosion)

(viii) Water

Maintaining or enhancing the quantity and quality of rivers and groundwater and respecting formal and customary water rights

(ix) Air

Mitigation of air pollution and limitations/restrictions on open air burning as part of the production cycle

(x) Waste

Reduction, treatment and disposal of waste to avoid environmental contamination

(xi) Crop Management and Agrochemical Use

To use best practices of storage, handling and disposal of fertilizer and agrochemicals; application rates; Use of integrates pest management system and other non-chemical systems

(xii) Direct Land Use Changes

Restrictions related to the conversion of areas considered to have high conservation value, which can include degraded pasture areas (the requirements vary among the standards and the European Union has not yet defined maps of high conservation areas)

(xiii) Social and Environmental Impact Assessment

Preparation or existence of official document specifying how social and environmental impacts of operations are identifies, monitored and mitigated

(xiv) Rural and Social Development

Provision of social benefits to employees and social surroundings and implementation of actions to promote social development and improvement of socioeconomic status of local stakeholders. Plus assessing and mitigating negative impacts on communities and groups (women, youth, children and indigenous communities)

(xv) Contractors and Suppliers

Existence of requirements for contractors and suppliers to comply with human rights and labor standards

(xvi) Engagement and Communications with Stakeholders

Existence of requirements in the context of implementing processes or structures (governance) to guarantee multiple and relevant stakeholder participation throughout stakeholder consultation phases and certification process.

(xvii) Economic Viability and Production and Processing Efficiency

Using all resources efficiently, using less inputs to generate more outputs. Promoting long term economic viability of business

(xviii) Food Security

Assessing the impacts that biofuel production/processing may have on the production, availability, and prices of food. Producers and processors may be using food or land for biofuels that could be used to grow food for local communities.

The first discussion of the group section aimed to assess how difficult it is to be compliant (or keep being compliant) with each sustainability requirement. The participants had to choose which alternative they considered most appropriate for each requirement: (i) Easily compliant; (ii) Compliant with only few difficulties; (iii) Compliant with great difficulties; (iv) Very hard to be compliant; (v)neutral or irrelevant or not applicable.

As for the impact of the sustainability requirement on each dimension, we aimed to identify:

(i) Technical impacts

If the sustainability requirement will have positive or negative impacts on the level of technical risks the economic agents operate today.

i.e.: technical complexity, need for new or external technologies and/or qualified personnel, new processes impacting production capacity.

(ii) Financial Impacts

If the sustainability requirement will have positive or negative impacts on the Business Plan the economic agents have today.

i.e.: investment (capital expenses and operational expenses), profit margins, payback period.

(iii) Commercial Impacts

If the sustainability requirement will have positive or negative impacts on the level of commercial risks the economic agents operate today

i.e.: meeting customer demands, modification of channels, and access to raw materials or other essential supply components.

The results are presented according the group of feedstock. The option for focusing the analysis of the sustainability gaps and impacts on the feedstock itself, rather than on the industrial process, is justified because the main sustainability gaps and impacts reported by the stakeholders were related to feedstock production. Furthermore, with the exception of carbon dioxide emissions, which is related to the entire production process, all parameters used by the sustainability standards are directly related to feedstock production. The results are presented, for each feedstock group, according to the compliance gaps and impacts on the three dimensions.

9.1.3.1 Sucrose

9.1.3.1.1 Sustainability gaps

Considering the 16 requirements[16] analyzed by the stakeholders in the sucrose group's discussion, it can be observed in **Figure 58** that the great majority of the requirements were considered to be in the category "Compliant with only few difficulties", and two of them were considered to be "Easily compliant". Furthermore, three of the requirements were considered to be compliant with great difficulties and one of them very hard to be compliant.

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[16] There was not enough available time to discuss all of the 18 requirements.

Sustainability Requirement	Sucrose
Air	🟩
Biodiversity and Ecosystems	🟨
Contractors and Suppliers	🟥
Crop Management and Agrochemical Use	🟨
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	No answer
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟩
Food Security	No answer
GHG emissions	🟩
Human Health and Safety	🟩
Land Rights	🟦
Laws and International Conventions	🟨
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟦
Water	🟩

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	**Easily compliant**	**Compliant with only few difficulties**	**Compliant with great difficulties**	**Very hard to be compliant**

Figure 58 Sucrose: Evaluation of the degree of difficulty to meet requirement.

The most difficult requirement to be met was considered the need for contractors and suppliers to comply with the labor and environmental norms. There is a consensus among the stakeholders that major compliance difficulty is related to sugarcane independent suppliers, which should also be compliant with the requirement[17].

Besides the difficulty with the contractors and suppliers, the main compliance difficulties were related to: (i) *national laws and regulations*; (ii) *biodiversity and ecosystem*; (iii) *crop management and agrochemical use*.

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[17] Ethanol plants in Brazil are usually vertically integrated through sugarcane production. The sector comprises 70 thousand independent sugarcane producers, accounting for 25% of national sugarcane production; 75% of sugarcane comes from self supply of vertically integrated mills (mills have sugarcane fields plus processing plants).

As regards *international laws and international conventions* it was considered that they are not a problem for the producers to meet. Laws governing pesticides are not a problem also. However, *national laws and regulations* were considered a concern both for the stakeholders and for some panelists. The large number of social and environmental laws and regulations in Brazil, some conflicting, makes their application difficult.

They evidenced that there are different interpretations of the law (there is a lack of knowledge on how to apply some laws and regulations) that contribute to non compliance of some of them. As standards require compliance with national legislation, some difficulties arise in meeting this requirement.

It is not impossible to comply with the legislation (there are already many companies certified), but it requires considerable investments. The Brazilian Forest Code was cited as an example: there are many items that need a lot of investment, as well as items that mills have difficulty to accomplish.

Specifically on the compliance with the national *social legislation and norms*, it was emphasized that some labor laws are not adapted to the rural context. With regard to the use of *Personal Protective Equipment* by rural workers (as required in the legislation), it was mentioned that they are not adapted to rural workers, which can cause compliance difficulties.

Another consideration was that, although labor conditions have improved in the recent years (State of São Paulo presents the best social indicators, the new producing states also have good indicators), this is still an issue in some regions, especially considering small independent sugarcane suppliers.

As for the *biodiversity and ecosystem* requirement, it was considered that it can be accomplished with great difficulties, mainly due the need for investments. There are no technical difficulties in meeting the requirement to preserve biodiversity, but there is lack of investment in conservation areas. The technology exists, and producers should use the information they have on ecosystems to improve biodiversity.

Another requirement that is considered difficult to comply with is related to *crop management and agrochemical use*. For instance the case of vinasse (by-product of ethanol production), which was seen by the stakeholders group as a fertilizer. The conformity with the certification schemes regarding the use of vinasse depends on the established amount allowed by the certification standard. In Brazil, there is a specific legislation for fertilizer, but if one of the certification schemes sets a different limit, it creates a divergence and increases compliance difficulty.

Compliance with *crop management and agrochemical use* depends upon the maximum level established by the certification schemes. Besides, the compliance difficulty varies among regions and soil situation (physical and chemical conditions of different soils may require more or less fertilizer), and the type of fertilizer needed.

The requirements that were classified in the category "Compliant with only few difficulties" are: (i) *Employment*, *Wages and Labor Conditions*; (ii) *Human Health and Safety*; (iii) *Soil*; (iv) *GHG emissions*; (v) *Air*; (vi) *Direct Land Use Changes*; (vii) *Social and Environmental Impact Assessment*; (viii): *Engagement and Communications with Stakeholders*.

Considering "*Employment, Wages and Labor Conditions*" and "*Human Health and Safety*" requirements: it was considered that when the sugarcane production is under the control of the mills, there is no difficulty in meeting the requirements. Also, when activities agricultural are mechanized (planting and harvesting sugarcane), is not difficult to enforce the law (given that the main difficulties are linked to employees of manual cutting).

It was recognized that since 2005, labor conditions have improved a lot in the sugarcane sector. There may still be isolated cases of problems, but generally producers meet the standards. As mentioned before, difficulties arise from the large number of laws and rules and due to the lack of a clear interpretation. However, it was emphasized that compliance with these requirements can be more difficult for the independent sugarcane producers, mainly the small ones.

As regards the potential of *GHG emissions reductions*, there was a consensus among the stakeholders regarding the classification of this requirement as “compliant with few difficulties”. There are many studies (national and international) showing that the production of ethanol from sugar cane in Brazil reduces GHG emissions (including American studies).

However, there are some measurement issues. The measurement of GHG varies according to the certification scheme: RSB is more difficult than Bonsucro. There are still methodological uncertainties regarding how to measure GHG emissions, especially regarding whether the Indirect Land Use Change – ILUC – should be considered or not.

Exemplifying the difficulty of measurement and data needed to prove GHG reductions: if an area of pasture is used to plant sugarcane, it is necessary to have information from previous years of the pasture area: whether it was degraded pasture or not in 2008 (the cutoffyear for Bonsucro, RSB, EU, RED and ISCC) or in 2009 (for the RSB Global Standard). Often, there is no data for the previous years; the images of the Satellite maps for those years are frequently of poor quality. This way, in some cases there are no available data to assess GHG reductions.

Although Indirect Land Use Changes (ILUC) was considered a difficult issue to be overcome, efforts should be dispended to find an adequate methodology or a harmonization of the existing ones as this is an especially important matter in South American ecosystems.

Concerning the related matter of “*Land Use Change*” requirement (also considered in the category of those requirements “compliant with few difficulties”) accounts for the direct change of land use caused by bioenergy crops: major difficulties stems from the interpretation of what is *degraded area*, and from the data availability to prove that the expansion of sugarcane occurred over the degraded area.

As in the previous case (*CO_2 emissions reduction* requirement) it is necessary to have a database to prove that sugarcane was really planted over a degraded area. If it can be proven, there is no problem to comply with the requirement, because this area is not considered “high conservation value” area. The important variable is whether significant biodiversity existed at the time of the sugarcane planting.

The calculation of LUC is different according to the classification of the previous area (degraded natural pasture or degraded artificial grass). In Brazil there are a lot of artificial pastures, so the classification of the grass as “natural pasture” or “artificial grass” is not simple.

Besides, to carry out the calculations it is important to go back to the time when the standards were implemented. Some companies find it difficult to retrieve the information on what used to be in the area before the year 2008 (or 2009). The satellite technology (and its interpretation) is an important issue.

In the border regions, it can be more difficult to comply with this requirement due to the lack of data. For the states of São Paulo and Minas Gerais, which have more data, it is easier to prove (there is a consolidated usage history).

As for "*Soil*" requirement, the stakeholders' opinions varied a lot. One of them thought that the vinasse disposal should be considered in this requirement (because someone believes that it contaminates the soil), while the others thought that it should be considered in the "agrochemicals or nutrient" requirement (this was the final decision of the group).

As for compliance with the "*soil*" requirement, it was found that soil management in Brazil with mechanization activities is not a problem. The group thinks that the compliance with this requirement varies among producer states.

Concerning compliance with the "*water*" requirement, it was considered that it can be accomplished with only few difficulties. The majority of sugarcane is not irrigated. Most use of water in sugarcane production is to extinguish the fire when it happens in the fields. It was observed that it is important to avoid the water contamination with vinasse (in this sense the limits of vinasse disposal in the soil established in the legislation must be taken into consideration).

One of the stakeholders suggested that the analysis should consider the entire production process and not only the agricultural area, since the industrial process could cause environmental impacts. Future research should take into consideration the entire value chain, which will require a database.

As for the "*Land Rights*" and "*Waste*" requirements, both were considered easily to comply with.

The majority of the stakeholders presented in the sucrose group agreed that the ethanol production brings positive impacts to rural development (which spreads to neighboring cities), mainly related to job creation, income generation, schooling and training improvements.

9.1.3.1.2 Technical Impacts

For all dimensions (Technical, Financial, Commercial), the stakeholders' opinions are that the impacts vary when considering the short run or the long run. When applicable, they can be negative in the short run and positive in the long run, as discussed below.

Considering the *Technical Impacts*, the sustainability requirement can cause *positive, negative or neutral impacts* on the level of technical risks the economic agents operate with today (to be compliant with the requirement can imply changes in technical complexity, need for new or external technologies and/or qualified personnel, new processes impacting production capacity, and so on).

As for the stakeholders' opinions on the impact of the sustainability requirement on the *Technical Dimension*, they considered that eight requirements will cause negative impacts; seven are neutral, and one will have a highly negative impact on the technical risk, as observed in **Figure 59**.

Sustainability Requirement	Sucrose
Air	🟨
Biodiversity and Ecosystems	🟨
Contractors and Suppliers	🟥
Crop Management and Agrochemical Use	🟨
Direct Land Use Changes	🟨
Economic Viability and Production and Processing Efficiency	No answer
Employment, Wages and Labor Conditions	⬜
Engagement and Communications with Stakeholders	⬜
Food Security	No answer
GHG emissions	🟨
Human Health and Safety	⬜
Land Rights	⬜
Laws and International Conventions	⬜
Rural and Social Development	⬜
Social and Environmental Impact Assessment	🟨
Soil	🟨
Waste	⬜
Water	🟨

⬜ **Neutral or irrelevant or not applicable**	🟦 **Highly positive**	🟩 **Positive**	🟨 **Negative**	🟥 **Highly negative**

Figure 59 Sucrose: Impact of Sustainability Requirement on Technical Risks.

The reason they considered that most of the requirements cause negative impacts in the short run is the necessary investments to adopt new technologies. For sugarcane suppliers the impact is considered even more negative, due small production scale, lack of credit, etc.

Compliance with the social and environmental legislation does not necessarily require a new technology to be adopted or developed (for instance mechanical agricultural activities), rather it requires the adoption of an existing technology, usually more capital intensive than the one used.

Concerning the impacts of the requirements *Employment, Wages and Labor Conditions and Human Health and Safety*, the negative impacts in the short run are related to the improvements in housing, training, and safety equipment. The national norm “NR-31” is very specific and requires many changes. However, in the long term, the use of more advanced technologies can contribute to better working conditions, increase in labor productivity, and so on, resulting in positive impacts.

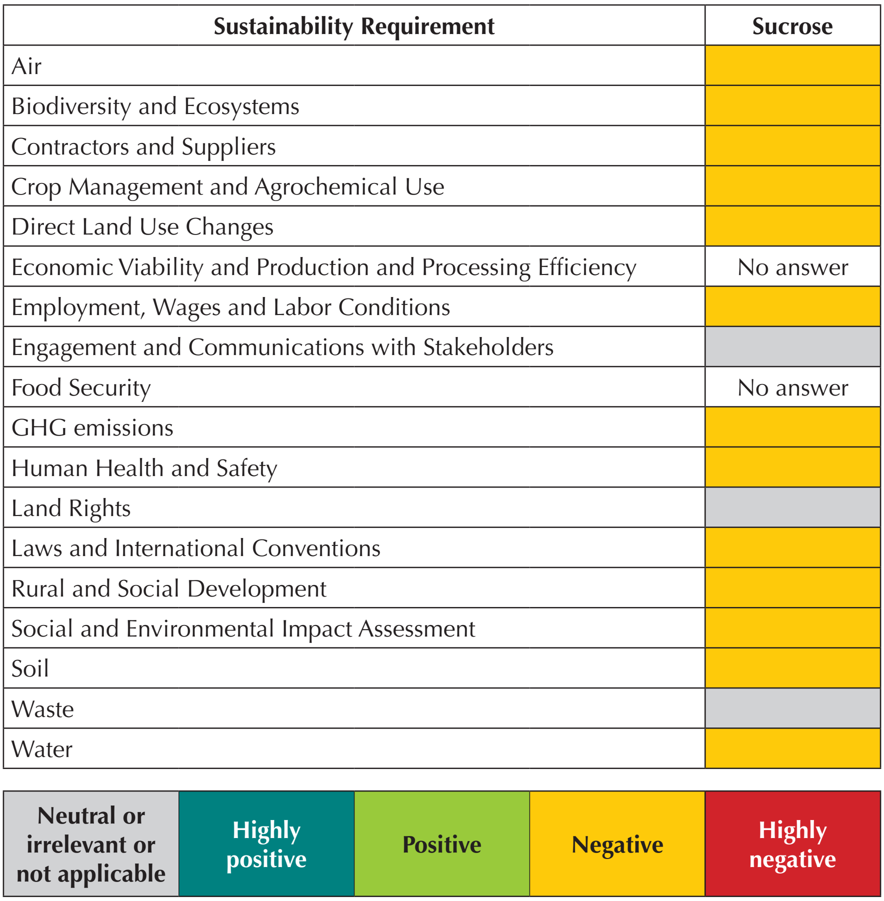
As regards the impacts of the *CO_2 emissions* requirement, the negative side for the producer is to find alternatives for the use of fertilizers. The positive aspect is that this improves the CO_2 calculation, where the producers need to improve accounting. The biggest impact in the technical risk was considered the methodology for calculations of land use change.

As regards the impact of *Biodiversity and Ecosystems*, it was considered that there is no technical risk, because the technology is available, it is just a matter of implementing the technology to improve biodiversity.

In conclusion, the impacts were considered negative (or neutral) in the short term, and positive in the long term.

9.1.3.1.3 Financial Impacts

Considering the impacts of the sustainability requirements on the Financial Impacts, they were considered mostly negative in the short term (**Figure 60**). In the long term, some could be considered positive due to higher rates of return.



Sustainability Requirement	Sucrose
Air	🟨
Biodiversity and Ecosystems	🟨
Contractors and Suppliers	🟨
Crop Management and Agrochemical Use	🟨
Direct Land Use Changes	🟨
Economic Viability and Production and Processing Efficiency	No answer
Employment, Wages and Labor Conditions	🟨
Engagement and Communications with Stakeholders	⬜
Food Security	No answer
GHG emissions	🟨
Human Health and Safety	🟨
Land Rights	⬜
Laws and International Conventions	🟨
Rural and Social Development	🟨
Social and Environmental Impact Assessment	🟨
Soil	🟨
Waste	⬜
Water	🟨

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	Highly positive	Positive	Negative	Highly negative

Figure 60 Sucrose: Impact of Sustainability Requirement on Financial Risks.

As mentioned before, the impact of meeting the requirements related to employment and labor conditions is negative in the short term, because of investments in training, housing, safety equipment, etc. However, it can be positive in the long term, because it can increase productivity.

Concerning *CO_2 emissions* requirement, it was considered that there is a financial risk in the short run due the adoption of the new technology. For instance, to reduce CO_2 emissions, the use of mechanical harvesting can cause problems such as soil compaction and yield reduction. But on the other hand, it can be positive in the long run, because trash preservation in the soil can lead to increased productivity. Once the new system is in place, the workers are trained, new varieties of sugarcane introduced, etc., the productivity can increase.

In general, negative financial impacts in the short term and positive in the long term.

9.1.3.1.4 Commercial Impacts

The commercial impacts were all considered positive (**Figure 61**).

Sustainability Requirement	Sucrose
Air	🟩
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟦
Economic Viability and Production and Processing Efficiency	No answer
Employment, Wages and Labor Conditions	🟦
Engagement and Communications with Stakeholders	🟩
Food Security	No answer
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟩
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	⬜
Water	🟩

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	**Highly positive**	**Positive**	**Negative**	**Highly negative**

Figure 61 Sucrose: Impact of Sustainability Requirement on commercial Risks.

The explanation for considering the impacts in the *Commercial Aspect* as positive is that if the practices adopted are not in accordance with the law, it is too difficult to market or export the product. The higher the compliance with the requirements is, less the commercial risk.

Customers want effective compliance; they concern themselves with the regulations and sustainability criteria. Companies not want their image linked to sugar production through bad working conditions, environmental degradation etc.

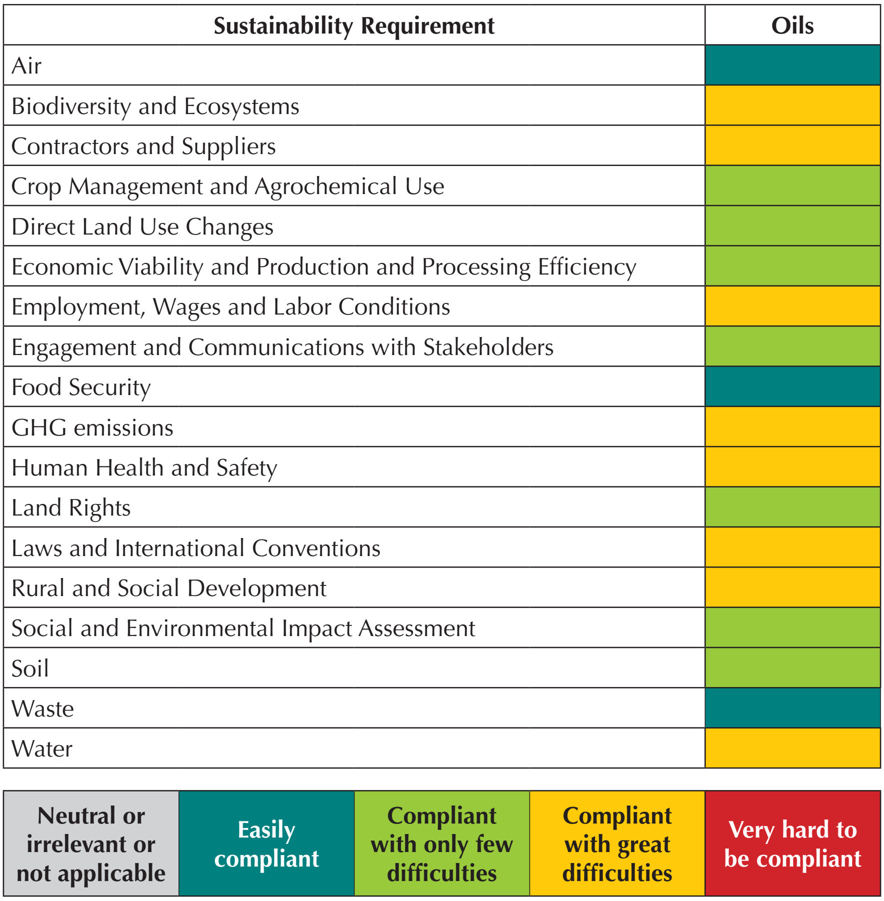
9.1.3.1.5 Sucrose: Summary

Compliance	- Social: great number of laws and regulations; different interpretations and lack of knowledge on how to apply laws; small and/or independent producers have more difficulty to comply; labor laws not adapted to the rural context; issue in some regions, especially with independent suppliers; difficulties with documentation on land rights, especially in some regions.
	- Rural development: job creation, income generation, improve schooling and capacitation
	Environmental: The compliance of some requirements caries among regions and soils situation (Example: the limit of nitrogen content established by standards: compliance depends of the situation of the soil)
	Main difficulties related to:
	- (i) biodiversity and ecosystem; (ii) crop management
	- Land Use Change: compliance different among regions: SP e MG ok; Others: may have lack of data to prove that the area was a degraded area
	- Vinasse: some states have legislation, others don't. Depending on the standard, criteria can be easy or difficult to comply
	- Economic: standards are focused on production efficiency of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.
Technical Impacts	The impacts varies if we are talking about the short run or long run. Are negative in the short run, and positive in the long run.
	- For sugarcane suppliers even more negative (production scale, etc.)
Financial Impacts	Financial: all negatives in the short run. Can increase productivity and be positive in the long run.
	- Investment: training and qualifying people (mechanical harvesting); equipment; production scale
Commercial Impacts	All positives

9.1.3.2 Oils

9.1.3.2.1 Sustainability gaps

Considering the requirements analyzed by the stakeholders in the oil group's discussion, it can be observed in **Figure 62** that three requirements were considered in the category "easily compliant"; and seven of them were considered "Compliant with only few difficulties". Furthermore, the stakeholders that were in these groups classified eight of the requirements to be "compliant with great difficulties".



Sustainability Requirement	Oils
Air	🟦
Biodiversity and Ecosystems	🟨
Contractors and Suppliers	🟨
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟨
Engagement and Communications with Stakeholders	🟩
Food Security	🟦
GHG emissions	🟨
Human Health and Safety	🟨
Land Rights	🟩
Laws and International Conventions	🟨
Rural and Social Development	🟨
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟦
Water	🟨

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	**Easily compliant**	**Compliant with only few difficulties**	**Compliant with great difficulties**	**Very hard to be compliant**

Figure 62 Oils: Evaluation of the degree of difficulty to meet requirement.

The following explanations justify the option chosen for each category. In the easily compliant categories are the following requirements: *air, food security and waste*. Concerning the waste, it was considered that the oil feedstock produces little or no harmful waste. Co-products (cakes) have several uses (animal feed, fertilizer). Regarding food security, agricultural feedstocks for bioenergy in Brazil nowadays do not compete with food production (CGEE, 2012; GOLDEMBERG, 2008; GOLDEMBERG et al., 2008; NASSAR et al., 2011; NEVES et al., 2011).

The requirements *Land rights; Soil; Crop Management and Agrochemical Use; Direct Land Use Changes; Social and Environmental Impact Assessment; Engagement and Communications with Stakeholders; Economic Viability and Production and Processing Efficiency* were in the "Compliant with only few difficulties" category.

Land use change was considered easy or neutral to be complied with on older farming areas, but may be difficult in expansion areas (agricultural frontiers) and also for palm oil producers.

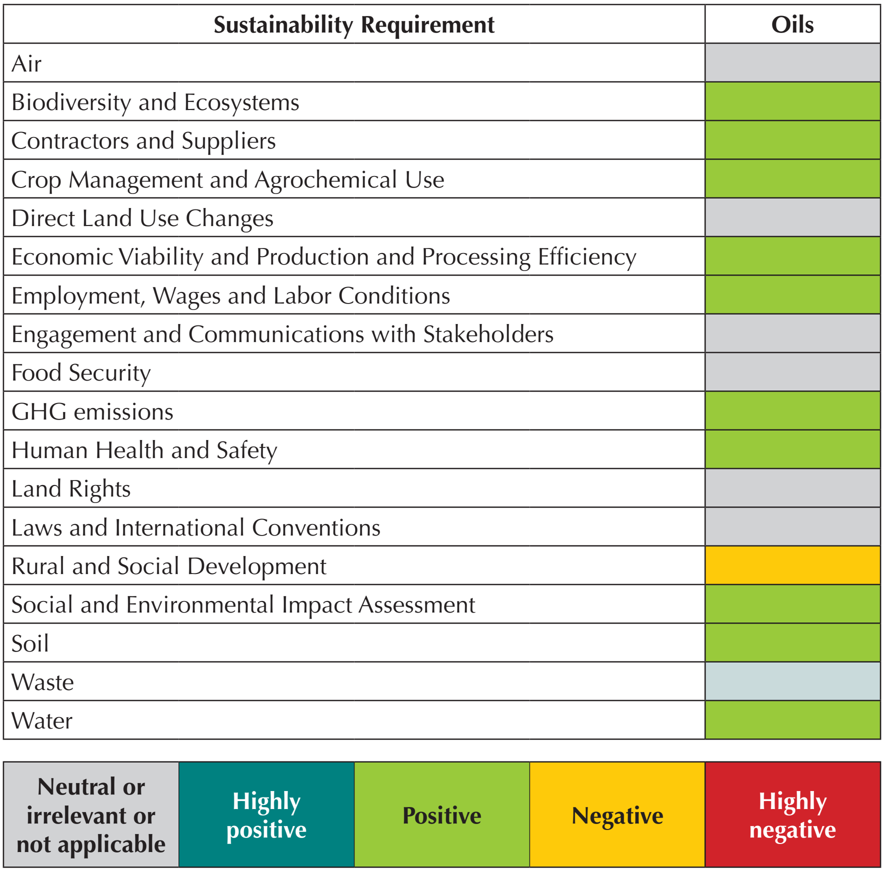
Concerning *Social and Environmental Impact Assessment*, it was emphasized that compliance depends on production scale: very hard to comply for smallholders; and compliant with few difficulties for larger farmers.

The category "*Compliant with great difficulties*" took into account *Employment, Wages and Labor Conditions; Human Health and Safety; CO_2 emissions; Biodiversity and Ecosystems; Water; Rural and Social Development; Contractors and Suppliers*. Reasons to justify the option include the difficulties to calculate CO_2 emissions, which depends on the crop, being more favorable for palm oil than for soybean. On the other hand, ILUC may be greater for palm, although there are still no widely accepted methodologies to address this issue. Concerning labor conditions (human rights and labor), compliance may be difficult because it is dependent on third parties (suppliers).

The difficulties identified for the oil group, especially regarding GHG emissions calculations and biodiversity, are concerning and need to be addressed. The development of standard protocols and methodologies are important to be considered.

9.1.3.2.2 Technical Impacts

The majority of the impacts of sustainability requirements on technical risks were perceived as positive. Specifically on the impact of *Law and International Conventions*, the technical impact was considered positive because it leads to the use of more skilled workers (**Figure 63**).



Sustainability Requirement	Oils
Air	⬜
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	⬜
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	⬜
Food Security	⬜
GHG emissions	🟩
Human Health and Safety	🟩
Land Rights	⬜
Laws and International Conventions	⬜
Rural and Social Development	🟨
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	⬜
Water	🟩

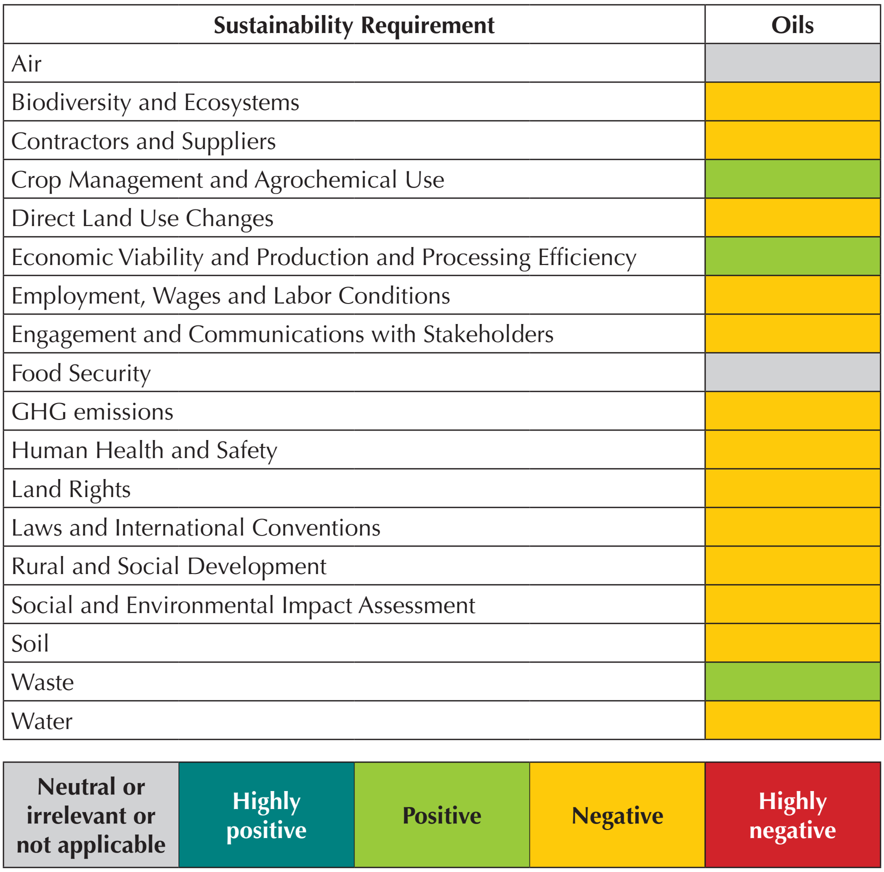
⬜ Neutral or irrelevant or not applicable	🟦 Highly positive	🟩 Positive	🟨 Negative	🟥 Highly negative

Figure 63 Oils: Impact of Sustainability Requirement on Technical Risks.

Concerning the impact of the *Water and Soil* requirement, the positive impact on technical risk can be explained due to the adoption of best practices (avoiding water contamination with pesticides, controlling erosion). However, it was emphasized that this would cause cost increases for the business in the short run. This group did not take into consideration impacts in the short run or in the long term as the other did.

9.1.3.2.3 Financial Impacts

Only three requirements were perceived as causing positive financial impacts (Waste, Crop Management and Agrochemical Use and Economic Viability and Production and Processing Efficiency). Besides those ones considered neutral or irrelevant, all other requirements were considered as causing negative financial impacts, due the need of investments to accomplish them (**Figure 64**). This group did not take into consideration impacts in the short term or in the long term as the other did.



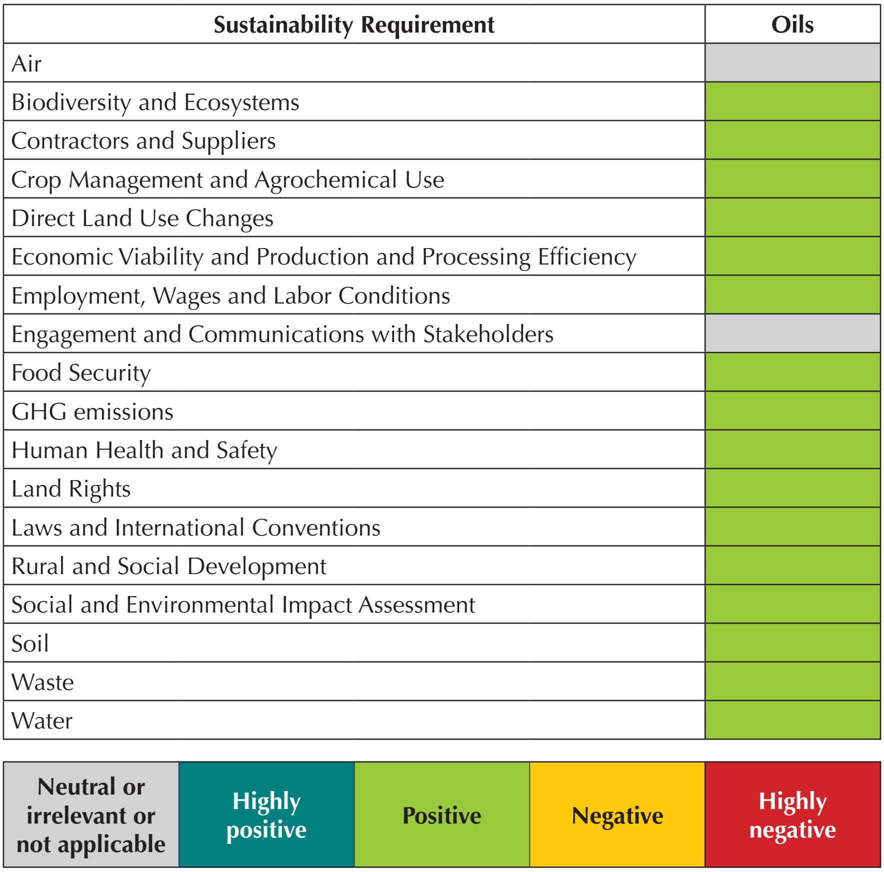
Sustainability Requirement	Oils
Air	⬜
Biodiversity and Ecosystems	🟨
Contractors and Suppliers	🟨
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟨
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟨
Engagement and Communications with Stakeholders	🟨
Food Security	⬜
GHG emissions	🟨
Human Health and Safety	🟨
Land Rights	🟨
Laws and International Conventions	🟨
Rural and Social Development	🟨
Social and Environmental Impact Assessment	🟨
Soil	🟨
Waste	🟩
Water	🟨

⬜ Neutral or irrelevant or not applicable	🟦 Highly positive	🟩 Positive	🟨 Negative	🟥 Highly negative

Figure 64 Oils: Impact of Sustainability Requirement on Financial Risks.

9.1.3.2.4 Commercial Impacts

Compliance with all of the requirements was considered to have positive commercial impacts (**Figure 65**). The main reasons cited were: compliance with legislation will increase costs, but will have a positive impact with customers and it is favorable for trade; if land rights are not proven there would be problems with access to credit (negative financial impact), as well as to market the product.



Sustainability Requirement	**Oils**
Air	⬜
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	⬜
Food Security	🟩
GHG emissions	🟩
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟩
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟩
Water	🟩

Neutral or irrelevant or not applicable	**Highly positive**	**Positive**	**Negative**	**Highly negative**

Figure 65 Oils: Impact of Sustainability Requirement on Commercial Risks.

9.1.3.2.5 Oils: Summary

Compliance	- Social: Human rights and labor issues: difficult to depend on third parties; Comply with the laws will increase costs but will have a positive impact with customers; If land rights are not proven there would be problems with access to credit (financial) as well as to market the product; Small producers may have more difficulty to comply; Brazilian feedstocks for bioenergy are not competing with food. There is a positive impact for clients, therefore improves commercial impacts. Food versus fuel may be a problem in the future.

Compliance	- Environmental: Comply with the laws will increase costs but will have a positive impact with customers; Small producers may have more difficulty to comply; Difficulties with calculating CO_2. Depends also on crop. More favorable for palm oil than for soybean. On the other hand ILUC may be greater for palm; Better farming practices may have a positive technical impact but there are several unknowns on this topic; LUC: Easy or neutral on old farming areas but may be difficult on the frontiers; may be difficult for palm oil; Great difficulties for expansion of feedstock production.
	- Economic: standards are focused on production efficiency of feedstcoks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.
Technical Impacts	The impacts vary. They can be negative in the short term, and positive in the long term. All negatives in the short term. - Social impact: positive because of more qualified personnel; comply with law is favorable for trade. - Impacts will be different for each region: more difficult in the lands of frontier.
Financial Impacts	Financial: the financial impact is negative. However, the additional cost could affect the commercial impacts. If the image of the feedstock/product was positively affected by compliance with the requirement, a favorable commercial impact shall also be considered.
Commercial Impacts	The group had some difficulty to decide when the net commercial impact was negative or positive.

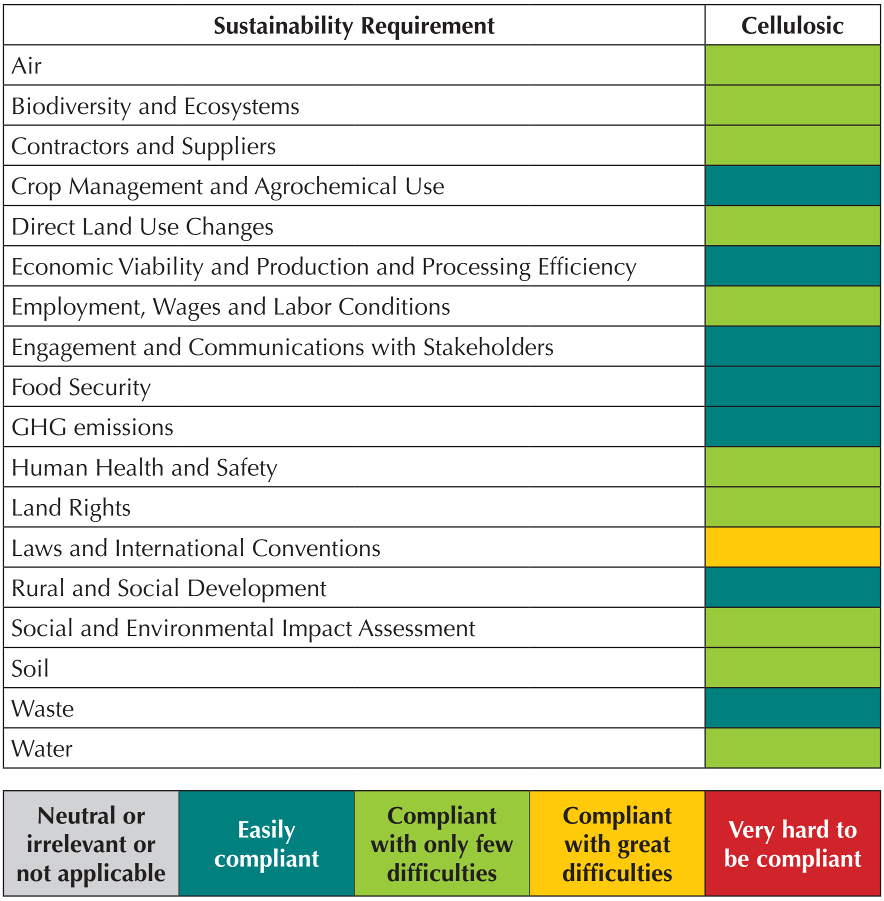
9.1.3.3 Lignocellulosics

9.1.3.3.1 Sustainability gaps

The lignocellulosic group comprises mainly sugarcane bagasse and forestry wood residues, although agricultural residues and grasses were also mentioned occasionally in the discussions. Given that the lignocellulosic feedstocks selected are mostly from residues, the general evaluation is that the lignocellulosic group is able to comply with the majority of the sustainability requirements. Out of the 19 requirements, only one was considered possible to comply with great difficulties. The others were ranked as easily compliant and as compliant with only few difficulties.

The requirements considered as easily compliant are those in which the impacts are associated to the main product, such as sugarcane – in the case of sugarcane bagasse – and commercial forests – in the case of wood residues. The impacts associated with requirements such as *crop management and agrochemical use, economic viability and production and processing efficiency, engagement and communications with stakeholders, food security,* CO_2 *emissions, rural and social development* and *waste* are mostly attributable to the main products, which allow their residues to be easily compliant (**Figure 66**).

In the case of the requirements of *air, biodiversity and ecosystems, contractors and suppliers, direct land use changes, employment, wages and labor conditions, human health and safety, land rights, social and environmental impact assessment, soil and* *water*, the assessment was that, although the impacts are also attributable to the main product, the residues could not be dissociated from these impacts.



Sustainability Requirement	Cellulosic
Air	🟩
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟦
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟦
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟦
Food Security	🟦
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟨
Rural and Social Development	🟦
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟦
Water	🟩

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	Easily compliant	Compliant with only few difficulties	Compliant with great difficulties	Very hard to be compliant

Figure 66 Cellulosic: Evaluation of the degree of difficulty to meet the requirements.

The following explanations justify the option chosen for each requirement:

1. *Air*: associated to the slash and burning practices of sugarcane still used in the harvesting.
2. *Biodiversity and Ecosystems*: some regions in Brazil would have more difficulties to comply with the preservation of biodiversity and ecosystems, especially if the level of technology in production is too low or in frontier regions.
3. *Contractors and Suppliers*: integrated value chains (sugarcane and commercial forests) were considered as easily compliant, but non-integrated chains may face greater difficulties.
4. *Crop Management and Agrochemical Use*: GMO varieties were not considered and the only concern is vinasse application.

5. *Direct Land Use Changes*: it can be an issue in Cerrado's expansion frontier both for sugarcane and commercial forests.
6. *Economic Viability and Production and Processing Efficiency*: being residues, the economic viability of production is not an issue for cane bagasse and wood residues.
7. *Employment, Wages and Labor Conditions*: risks are never zero in labor conditions, although both sugarcane and commercial forests sectors have high standards.
8. *Engagement and Communications with Stakeholders*: this is a current practice in sugarcane and commercial forests sectors.
9. *Food Security*: it can be an issue in marginal areas but it is not relevant in general.
10. CO_2 emissions: even allocating some emissions in the production of the main product to the residues, CO_2 emissions reductions are high.
11. *Human Health and Safety*: varies according to the region where the feedstock is produced.
12. *Land Rights*: varies according to the region where the feedstock is produced.
13. *Laws and International Conventions*: although not discussed in detail, the general assessment is that there are international conventions that might not be easy to comply with.
14. *Rural and Social Development*: as a general evaluation, sugarcane and commercial forests production promote rural and social development.
15. *Social and Environmental Impact Assessment*: compliance with social and environmental regulations is an issue, especially in the case of independent sugarcane suppliers.
16. *Soil*: soil conservation needs to be improved in the production of sugarcane.
17. *Waste*: easily compliant because wastes from sugarcane and commercial forest production would have value and thus would not be disposed of.
18. *Water*: assuming production without irrigation, which is the majority of the cases for sugarcane and commercial forests, water usage is not an issue. However, water yield is a topic to be monitored in situations with certain types of land use changes. The issue of surface water contamination is also important and included in the principles and criteria of sustainability standards. However, it was not discussed specifically by the group. The Brazilian law addresses this to some extent.

9.1.3.3.2 Technical Impacts

Given that the feedstocks for cellulosic biofuels are residues, all impacts of sustainability requirements on technical risks were perceived as positive and highly positive. The assessment is that compliance with the sustainability requirements helps to reduce technical risks or to reinforce lignocellulosic biofuel as a strong alternative for renewable fuels in comparison with other sources of renewables (**Figure 67**).

Sustainability Requirement	Lignocellulosics
Air	🟩
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟦
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟦
Food Security	🟩
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟩
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟦
Water	🟩

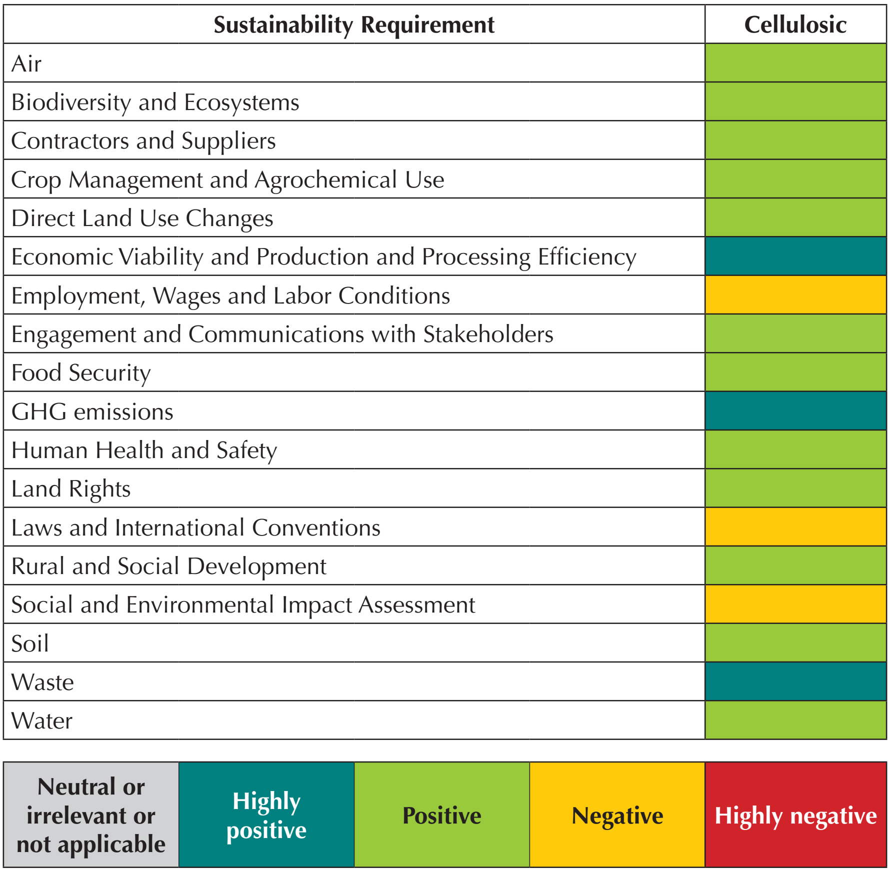
⬜ Neutral or irrelevant or not applicable	🟦 Highly positive	🟩 Positive	🟨 Negative	🟥 Highly negative

Figure 67 Lignocellulosics: Impact of Sustainability Requirement on Technical Risks.

9.1.3.3.3 Financial Impacts

The criteria used to analyze the financial impacts was to divide the impacts from sustainability requirements in two groups: one with the capacity to aggregate value to the final product and a second one that only generate additional costs without necessarily aggregating more value to the final product.

Based on these criteria, the requirements considered as only adding costs were employment, wages and labor conditions, laws and international conventions, and social and environmental impact assessment (**Figure 68**).



Sustainability Requirement	Cellulosic
Air	🟩
Biodiversity and Ecosystems	🟩
Contractors and Suppliers	🟩
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟦
Employment, Wages and Labor Conditions	🟨
Engagement and Communications with Stakeholders	🟩
Food Security	🟩
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟨
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟨
Soil	🟩
Waste	🟦
Water	🟩

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	Highly positive	Positive	Negative	Highly negative

Figure 68 Cellulosic: Impact of Sustainability Requirement on Financial Risks.

9.1.3.3.4 Commercial Impacts

Following similar criteria used in technical and financial risks, the impact of the sustainability requirement on commercial aspects was considered positive if it is able to aggregate value from a marketing perspective. Based on this criterion, all sustainability requirements were considered positive and highly positive (**Figure 69**).

Sustainability Requirement	Cellulosic
Air	🟩
Biodiversity and Ecosystems	🟦
Contractors and Suppliers	🟦
Crop Management and Agrochemical Use	🟩
Direct Land Use Changes	🟩
Economic Viability and Production and Processing Efficiency	🟦
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟦
Food Security	🟩
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	🟩
Laws and International Conventions	🟩
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟩
Waste	🟦
Water	🟩

⬜ **Neutral or irrelevant or not applicable**	🟦 **Highly positive**	🟩 **Positive**	🟨 **Negative**	🟥 **Highly negative**

Figure 69 Cellulosic: Impact of Sustainability Requirement on Commercial Risks.

9.1.3.3.5 Lignocellulosic: Summary

Compliance	- Social: compliance with some of the laws; Land rights: there are regions in which this must be a larger issue; depending on the region; Contractors and Suppliers: sustainability compliance would be much like positive in integrated value chains such as sugarcane and planted forests and systems that are able to generate by-products than systems dedicated to one product; integrated systems have different results than non integrated; issue of equivalence and overlapping of regulations and requirements, although we have two layers (national and international).
	- Environmental: compliance with some of the laws; CO_2 emissions calculation is a complex issue, depends on the feedstock, the process, local conditions, etc; Biodiversity: some regions and feedstocks where the compliance might be more difficult; assuming that water usage is not an issue compliance is easy; Water yield can be an issue depending the land use change; Biological control and chemical control (it is working); - LUC: Can be an issue for future expansion in the Cerrados. Comparing to other feedstocks it is creating value and positive impacts; issue of equivalence and overlapping of regulations and requirements, although we have two layers (national and international).

Compliance	- Economic: standards are focused on production efficiency of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.
Technical Impacts	- The group adopted a long term perspective, therefore positive and highly positive scales predominate in the responses
Financial Impacts	- The group adopted a long term perspective, therefore positive and highly positive scales predominate in the responses
Commercial Impacts	- Positive.

9.1.3.4 Wastes

9.1.3.4.1 Sustainability gaps

Differently from the other feedstocks in which the sustainability requirements were assessed from the production perspective, mainly agriculture and forest for instance, the perspective used in wastes was more related to the process of collecting, cleaning and preparing the different types of wastes (flue gas, used cooking oil, municipal solid waste and animal fat), as well as the refining process.

The majority of the sustainability requirements were considered as easily compliant or compliant with few difficulties. The easily compliant requirements are those unrelated to the supply of waste. Waste supply is not associated to the use of land and does not use land as an input, which facilitates compliance with requirements associated to land use changes, land rights, biodiversity, food security and soil conservation.

Regarding the other requirements for which wastes can comply with only few difficulties, the explanations vary depending on the case. Air and water are inputs for the waste supply chain and depending on the type of the waste to be processed, those inputs can be intensively used. According to stakeholder discussions, the MSW and flue gas processes use more water than the used cooking oil and animal fat processes, due to water use in fermentation process compared to catalysis.

Waste processes can also generate products that need must be treated in order treatment and, therefore, some difficulties may appear to comply with sustainability requirements.

The requirements that were classified as compliant with only a few difficulties are not related to inputs, but to conditions not necessarily linked to the supply of the feedstock. On the economic viability requirement, some processes still need to be more efficient. Waste collection from landfills faces the problem of competition with large and informal labor (without formal labor contracts) communities that work in collecting and sorting trash in Brazil. Although there is space for improvement, big cities would probably be better positioned than small cities, since economies of scale apply across technologies and, therefore, aggregating a larger waste resource in one place is key. To develop a mechanism to communicate with the stakeholders of these communities can be a challenge.

In the case of MSW, protection of human health and safety needs strong improvements, although for other types of waste it is easy to comply with the requirements. Social development may be improved if existing workers are involved in sorting wastes for use in fuel production, however the level of informality in some cases may be a limiting factor.

Regarding the social and environmental impact assessment requirement, the perception is that compliance can be easier for waste than for other feedstocks, although transaction costs to carry out an impact assessment are high in Brazil.

Compliance with CO_2 emissions requirements depends on the type of waste. Some processes are extremely energy intensive, which can undermine CO_2 emissions reductions (although this depends on the system boundaries and on how the CO_2 emission are calculated and allocated). For flue gases primarily containing CO and $\mathrm{CO_2}$, hydrogen may be needed, and, therefore renewable hydrogen sources such as biomass syngas may be used to be compliant with $\mathrm{CO_2}$ emission requirements. In the MSW process, the biodegradable portion, can be compliant with great difficulties. Tallow and used cooking oil can comply more easily than the others, but also depend on specific situations.

Waste supply chains, in general, have several middlemen and intermediary agents, making traceability very hard to be implemented. Therefore, it was considered as very hard to be compliant (**Figure 70**), eventhough for industrial residues this may be easier.

Sustainability Requirement	Waste
Air	🟩
Biodiversity and Ecosystems	🟦
Contractors and Suppliers[1]	🟥
Crop Management and Agrochemical Use	⬜
Direct Land Use Changes	🟦
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟩
Food Security	🟦
GHG emissions	Varies
Human Health and Safety	🟩
Land Rights	⬜
Laws and International Conventions	🟦
Rural and Social Development	🟩
Social and Environmental Impact Assessment	🟩
Soil	🟦
Waste	🟩
Water	🟩

Note: [1] For industrial residues it can be considered as "Compliant with only few difficulties"

⬜	🟦	🟩	🟨	🟥
Neutral or irrelevant or not applicable	**Easily compliant**	**Compliant with only few difficulties**	**Compliant with great difficulties**	**Very hard to be compliant**

Figure 70 Waste: Evaluation of the degree of difficulty to meet the requirements.

9.1.3.4.2 Technical Impacts

In terms of the impacts on technical aspects, the majority of the requirements were considered as neutral, or irrelevant or not applicable. The requirements considered neutral are almost the same as those considered neutral in the previous section, plus the ones considered easily compliant because they are not related to waste supply. In this instance, the multiple neutral ratings reflect the minimal impact these feedstocks have on sustainability criteria.

In the case of requirements ranked with positive impacts, the main criterion was that the use of the waste for processing jet biofuels will improve the capacity of the industry to comply with the requirement and, therefore, reduce technical risks (**Figure 71**).

In several other requirements, the risks are different among the waste types (MSW, tallow, flue gas and used cooking oil) and depend on the process. In general, those sustainability requirements are expected to have highly positive or positive impacts.

The perception is that reducing CO_2 emissions increases technical complexity, although it would also push for innovation. There is a perception that, at the margin, it may be difficult to further CO_2 emissions reductions.

Sustainability Requirement	Waste
Air	Varies
Biodiversity and Ecosystems	⬜
Contractors and Suppliers[1]	⬜
Crop Management and Agrochemical Use	⬜
Direct Land Use Changes	⬜
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	Varies
Food Security	⬜
GHG emissions	🟨
Human Health and Safety	Varies
Land Rights	⬜
Laws and International Conventions	🟩
Rural and Social Development	⬜
Social and Environmental Impact Assessment	🟩
Soil	⬜
Waste	Varies
Water	Varies

Note: [1] LanzaTech considers as "Highly positive" for industrial residues

Neutral or irrelevant or not applicable	Highly positive	Positive	Negative	Highly negative

Figure 71 Waste: Impact of Sustainability Requirement on Technical Risks.

9.1.3.4.3 Financial Impacts

The requirements considered as neutral or irrelevant or not applicable are very similar to the previous section and, therefore, the reasons are the same: the requirement is not related to the supply of the waste.

Engagement with stakeholders, CO_2 emissions, human health and safety, law and international conventions and social and environmental impact assessment were considered as having positive impacts on financial risks of operating facilities. On the other hand, requirements perceived as directly associated to production costs, such as employment, wages and labor conditions, rural and social development and waste treatment, were considered as increasing financial risks.

In the case of water and air, additional treatments may increase investment costs but a more efficient process can economize on the use of the resource. For this reason, the impacts can be both positive and negative (**Figure 72**).

Sustainability Requirement	Waste
Air	Varies
Biodiversity and Ecosystems	⬜
Contractors and Suppliers[1]	⬜
Crop Management and Agrochemical Use	⬜
Direct Land Use Changes	⬜
Economic Viability and Production and Processing Efficiency	Varies
Employment, Wages and Labor Conditions	🟨
Engagement and Communications with Stakeholders	🟩
Food Security	⬜
GHG emissions	🟩
Human Health and Safety	🟩
Land Rights	⬜
Laws and International Conventions	🟩
Rural and Social Development	🟨
Social and Environmental Impact Assessment	🟩
Soil	⬜
Waste	🟨
Water	Varies

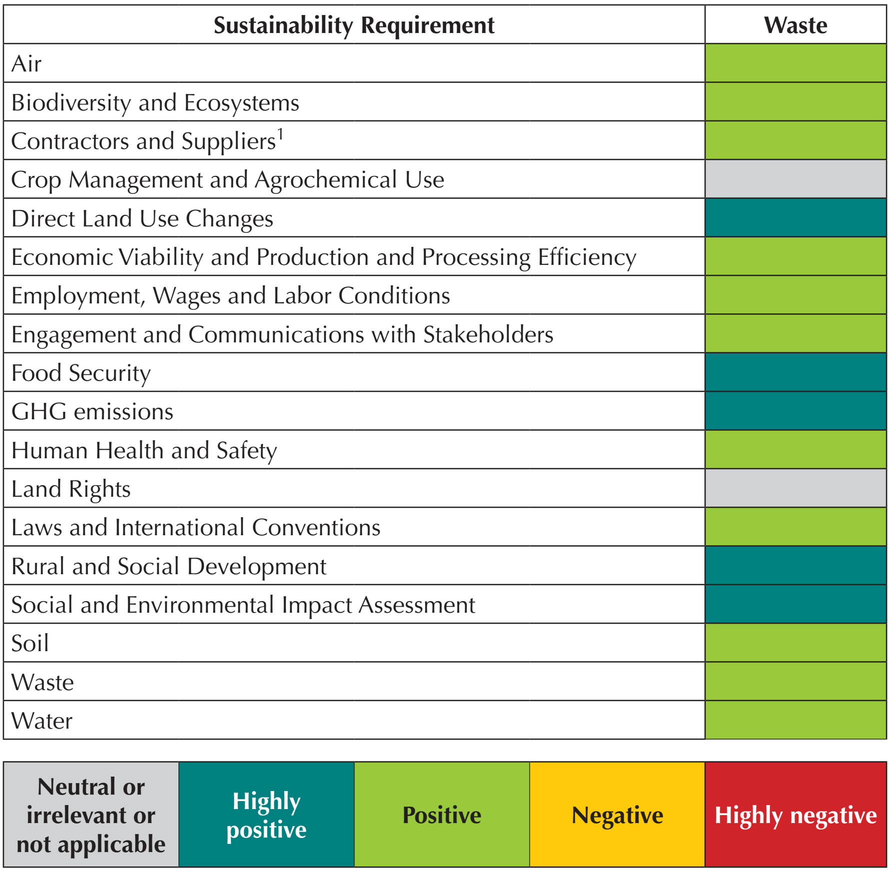
Note: [1] For industrial residues it can be considered as "Positive"

⬜ Neutral or irrelevant or not applicable	🟦 Highly positive	🟩 Positive	🟨 Negative	🟥 Highly negative

Figure 72 Waste: Impact of Sustainability Requirement on Financial Risks.

9.1.3.4.4 Commercial Impacts

The assessment of commercial risks was different from the technical and financial risks. The majority of the requirements were considered highly positive or positive (**Figure 73**). The main perception is that complying with sustainability requirements creates value in the market for fuels from wastes, acting as an incentive for waste value chains to adopt sustainability standards as a commercial strategy. The conclusion is that fuels from wastes are sustainable from a marketing perspective.



Sustainability Requirement	Waste
Air	🟩
Biodiversity and Ecosystems	🟩
Contractors and Suppliers[1]	🟩
Crop Management and Agrochemical Use	⬜
Direct Land Use Changes	🟦
Economic Viability and Production and Processing Efficiency	🟩
Employment, Wages and Labor Conditions	🟩
Engagement and Communications with Stakeholders	🟩
Food Security	🟦
GHG emissions	🟦
Human Health and Safety	🟩
Land Rights	⬜
Laws and International Conventions	🟩
Rural and Social Development	🟦
Social and Environmental Impact Assessment	🟦
Soil	🟩
Waste	🟩
Water	🟩

⬜ Neutral or irrelevant or not applicable	🟦 Highly positive	🟩 Positive	🟨 Negative	🟥 Highly negative

Figure 73 Waste: Impact of Sustainability Requirement on Commercial Risks.

9.1.3.4.5 Wastes: Summary

Compliance	- Social: Eye for conflicting laws. Careful not to inhibit process of developing solutions; formality or informality of waste collection and landfills. Room for improvement. May not be as easy to compliant. In the case of big cities, it will probably be easy, but in smaller cities it might be harder; Improve the safety of employees. Making conditions of workers better; Social Development: Infrastructure development, jobs. Consider financial difficulties that are involved. Different financial options that do not result in the same amount of social development.

Compliance	- Environmental: Eye for conflicting laws. Careful not to inhibit process of developing solutions; CO_2 emissions: some processes are extremely energy intensive. Compliance varies among process (easy to comply with difficult to comply) ; Increases technical complexity and push innovation. Maybe not very much of a margin to increases CO_2 reductions. Biodiversity: Easily compliant because there are no problems related. - Water: Processes with a lot of use of water (cooking oil); Animal fat: comply with great difficulties;
	- Economic: standards are focused on production efficie°ncy of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. - Price policies must be defined and should consider the positive externalities of biofuels.
Technical Impacts	Medium and long range. In the short run, start-up phase, may be negative. Positive: transform something bad into something good. Differences among waste feedstocks.
Financial Impacts	- Important to consider financial difficulties that are involved. - Laws will push technology development. This will have a positive impact on business plan. Understanding of what laws apply. - In the beginning it may be neg°ative. No personnel to employ because they must be trained - Business plan, you may get results later on. Getting money at lower interest rate (would also be positive).
Commercial Impacts	Positive: perception that using waste is a good thing. Not part of fuel and food debate

9.1.3.5 Overall view

Figure 74 provides an overall view of the whole of feedstocks groups regarding the classification of the requirement gaps. It can be observed that, for all groups, the following requirements were considered easily compliant or compliant with only few difficulties: Air; Direct Land Use Changes; Social and Environmental Impact Assessment; Waste; Engagement and Communications with Stakeholders; Soil; Waste.

Economic and Food Security requirements were considered also in these categories, however one of the groups did not evaluate these requirements.

The other requirements, as observed, vary according to the feedstock group.

9.1.3.5.1 Final Remarks

It is important to highlight, as emphasized by some of the presenters in 4th and 7th workshop, that sustainability should not be treated as static theme, since it is constantly changing and improving: "*Sustainability comes from continuous improvement in best practices through innovation*". From our point of view, both the criteria and the methods to assess compliance with them established by the main certification schemes evolve over time, as well as the indicators themselves.

In the specific case of agricultural feedstocks in Brazil, it is noteworthy that the sustainability agenda has become effective from the year 2000, when important improvements started to occur in the environmental and social sustainability indicators for some crops,

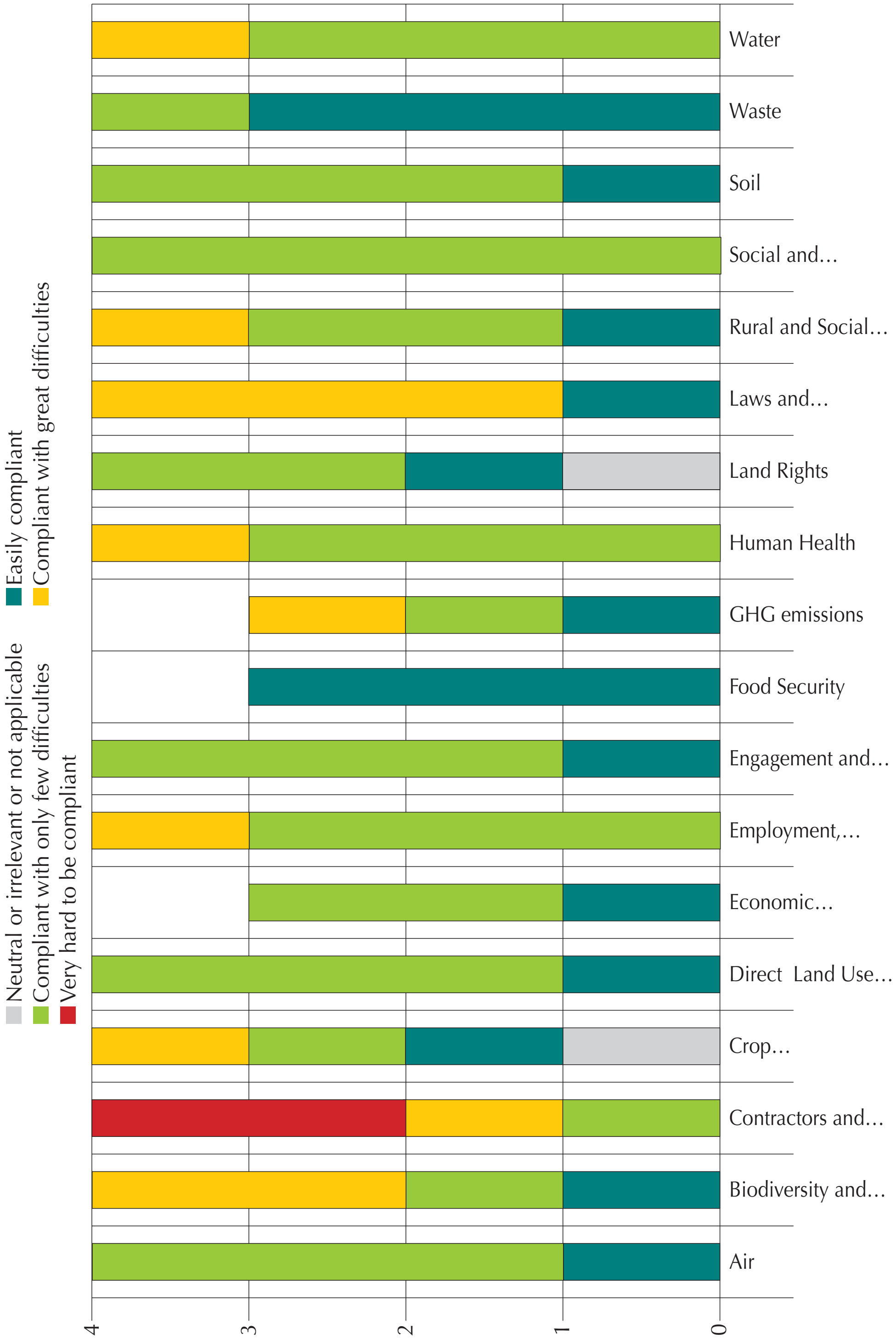


Figure 74 Overall evaluation of the degree of difficulty to meet requirement.

particularly soybean, cotton and sugarcane. In 7th Workshop, it was emphasized that positive advances in the sugarcane indicators ended up positively influencing some traditional agricultural crops that did not originally see themes related to sustainability as concerns.

With this, positive advances are expected from national producers through time.

Although there are important differences among the four groups of feedstocks, some general common considerations can be made regarding biofuels production and also related to the gaps to comply with the sustainability requirements.

Concerning the social area, the main positive impacts are the high potential of job creation and income generation, and the positive impacts on regional development. As for the sustainability requirement's gaps, several factors were emphasized that make compliance more difficult, such as the great number of labor laws and rules in Brazil, sometimes more strict than sustainability standards; different interpretations and the lack of knowledge on how to apply laws; and labor laws not adapted to the rural context. It was also noted that there is a need for qualification and training of workers.

As for the Environmental Aspects, the positive impact related to compliance with requirements is the reduction in CO_2 emissions compared to fossil fuels, especially in the sucrose and cellulosic groups, although there are still some difficulties with CO_2 calculation and data.

Macedo et al., (2008) analyzed the GHG emissions and mitigation for ethanol from sugarcane in Brazil for the 2002-2008 period and the expected changes in the expansion from 2008-2020. Regarding the land use changes (LUC) effects, ethanol expansion started in 2002 led to a very small use of native vegetation lands (less than 1%), and a large use of low productive pasture lands and some crop areas (soy and maize). The relatively small area used for the expansion was due to land availability[18], environmental restrictions, and local economic conditions. Growth scenarios for 2020 (reaching 60M m^3 ethanol) indicate the need for relatively small areas (approximately 5 Mha) as compared to the availability (non-used arable lands or degraded pasture lands). Thus if policy and law enforcement are implemented so as to ensure optimal land use for biofuels, they found that very little impact (if any) from LUC on GHG emissions is expected. Considering the local conditions in Brazil, Macedo et al., (2008) found the area needed for the expansion to be very small when compared with the area liberated with increased cattle raising efficiency (30 Mha) and other non-used arable land. They showed that sugarcane expansion has been independent (and much smaller) than of the growth of other agricultural crops. In all sugarcane expansion areas the eventual competition products (crops and beef production) also expanded.

An important issue is the food versus fuel debate, a global concern that has been widely addressed in the media and discussed by stakeholders in defining sustainability standards. Biofuel production using agricultural feedstocks (especially maize, sugarcane and cereals) is accused of displacing land that could be used to produce food, causing food prices to increase and threatening food security in certain regions. According to Rosillo-Calle (2012): "*biofuel production and food security needs to be complementary*". It is important to assess food security impacts from biofuel production, but without disregarding the positive impacts that the additional income has on agricultural productivity. It is equally important to remember the benefits that these alternative fuels generate if they meet their most important function, which is to reduce GHG emissions from the whole supply chain when compared to fossil fuels.

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[18] See Brazilian Sugarcane Agroecological Zoning (ZAE Cana) http://www.cnps.embrapa.br/zoneamento_cana_de_acucar/

In Brazil, there is enough available land for the production of food and biomass for biofuels (CGEE, 2012; GOLDEMBERG, 2008; GOLDEMBERG et al., 2008; NASSAR et al., 2011; ADAMI et al., 2012; NASSAR; MOREIRA, 2013). Agricultural expansion has been taking place in degraded pasture areas and productivity of livestock production has increased significantly, from 0.92 heads/hectare in 2000 to 1.15 heads/hectare in 2010 (FIESP; ICONE, 2012).

The great number of environmental laws and rules (sometimes more strict than sustainability standards) and legal uncertainty (changes in the Forest Code, law regulating the conditions for Foreign Investors) are considered difficulties to comply with the legal requirements.

Brazilian legislation establishes that at least 20% of the land of individual farms (50% to 80% in the Amazon region) be set aside under Legal Reservation in order to preserve natural resources, water sources, biodiversity, and shelter for the native fauna and vegetation. In addition, stretches of land along water bodies as well as those with slopes above 45° are Areas of Permanent Preservation and cannot legally be converted to production. Aspects of Brazilian legislation on sustainability issues and considerations about difficulties of law enforcement are discussed in **Box 1** below.

It was considered that it is possible to be compliant with national and international rules and norms, but this requires investments. In general terms, small and independent producers have more difficulty to comply with the requirements.

The need for a clear price policy for fuels was emphasized, in order to make the production economically sustainable and to attract private investments and the use of jet biofuels.

Furthermore, it is fundamental that certification initiatives make an effort to harmonize standards among themselves and also with national standards in order to minimize conflicts and to promote the main objective of certification, which are more sustainable operations. In addition, it is fundamental that these initiatives implement actions to increase knowledge on these sustainability standards and to educate growers and companies on how to apply them.

Box 1: Law Enforcement & Sustainability

Environmentally sustainable production of jet biofuel is a strategic objective of the aviation industry, therefore meeting sustainability standards is of great importance.

Brazilian laws are quite strict to protect natural resources, water and biodiversity. The Brazilian Forest Code is among the most restrictive legislation on land use. Labor laws are equally severe. However, complying with legality principles of sustainability standards is regarded as challenging, in some circumstances. Many laws and rules are complex, prone to different interpretation, and sometimes, as in the Forest Code, demand expensive investments to make up for land clearing done in the past under other legislation. Generally small and independent producers have even more difficulty to comply with the rules because of the high costs involved. In addition, the extensive Brazilian territory makes it more difficult to enforce some laws. Under these conditions the legal framework in place, which could be quite effective to guarantee high sustainability standards, often falls short of its objectives.

It is critical that the Action Plan for implementation of aviation biofuels in Brazil emphasize that companies, institutions, or farmers that receive any incentive or benefit from public policies that involve public funds, abide by the laws related to the sustainability of processes in the whole production chain. Proof of compliance must be tied to receiving any benefits.

Table 30 Feedstock compliance to sustainability laws and regulations.

FEEDSTOCK GROUP	SOCIAL	ENVIRONMENTAL	ECONOMIC
Sucrose/starch	• Great number of laws and regulations; different interpretations and lack of knowledge on how to apply laws; small and/or independent producers have more difficulty to comply; labor laws not adapted to the rural context; Personal Protective Equipment not adapted to rural workers; although labor conditions have improved, this is still an issue in some regions, especially with independent suppliers; difficulties with documentation on land rights, especially in some regions; • Rural development: job creation, income generation, improve schooling and training	• The compliance of some requirements varies among regions and soil situation • Main difficulties related to: - biodiversity and ecosystem; - crop management - Direct Land Use Change: compliance different among regions (e.g. good in São Paulo and Minas Gerais, but other states may have lack of data to prove that the area was a degraded area) • Vinasse: some states have legislation, others don't. Depending on the standard, criteria can be easy or difficult to comply with.	• Standards are focused on production efficiency of feedstock; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.
Oil	• Human rights and labor issues: Difficult to depend on third parties; Compliance with the laws will increase costs but will have a positive impact with customers; If land rights are not proven there would be problems with access to credit (financial) as well as to market the product; Small producers may have more difficulty to comply;	• Compliance with the laws will increase costs but will have a positive impact with customers; Small producers may have more difficulty to comply; Difficulties with calculating GHG. Depends also on crop. More favorable for palm oil than for soybean. On the other hand ILUC may be greater for palm; Better farming practices may have a positive technical impact but there are several unknowns on this topic; LUC: Easy or neutral on old farming areas but may be difficult on the frontiers; may be difficult for palm oil; Great difficulties for expansion of feedstock production; Brazilian feedstocks for bioenergy are not competing with food. There is a positive impact for clients, therefore improves commercial impacts. Food versus fuel may be a problem in the future.	• Standards are focused on production efficiency of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.

Table 30 Feedstock compliance to sustainability laws and regulations (continued).

FEEDSTOCK GROUP	SOCIAL	ENVIRONMENTAL	ECONOMIC
Lignocellulosic	• Compliance with most of the laws depends on the region; Land rights: there are regions in which this may be a larger issue; • Contractors and Suppliers: sustainability compliance would be easier in integrated value chains such as sugarcane and planted forests and systems that are able to generate by-products than systems dedicated to one product; integrated systems have different results than non- integrated; issue of equivalence and overlapping of regulations and requirements, especially since we have two layers (national and international)	• Compliance with most of the laws and standards is expected to be achievable because the impacts are attributable to the main product; GHG emissions calculation is a complex issue, depends on the feedstock, the process, local conditions, etc; Biodiversity: in some regions and feedstocks the compliance might be more difficult; assuming that water usage is not an issue compliance is easy; Water yield can be an issue depending the land use change; Biological control and chemical control; • LUC: Can be an issue for future expansion in the Cerrados. Compared to other feedstocks cellulosic is creating value and positive impacts; issue of equivalence and overlapping of regulations and requirements, especially since there are two layers (national and international)	• Standards are focused on production efficiency of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.
Wastes	• There is potential for conflicting laws. Careful not to inhibit process of developing solutions; informality of labor for waste collection and landfills. Room for improvement. May not be as easy to compliant. In the case of big cities, it will probably be easy, but in smaller cities it might be harder; Improve the safety of employees. Making conditions of workers better; Social Development: Infrastructure development, jobs. Consider financial difficulties that are involved. Different financial options that do not result in the same amount of social development	• There is potential for conflicting laws. Careful not to inhibit process of developing solutions; GHG emissions: some processes are extremely energy intensive. Compliance varies among processes (easy to comply with difficult to comply); Increases technical complexity and pushes innovation. Maybe not very much of a margin to increases GHG reductions. Biodiversity: Easily compliant because there are no problems related to land. • Water: Processes with high water demand (cooking oil); animal fat: comply with great difficulties; Water pollution must be addressed.	• Standards are focused on production efficiency of feedstocks; lack of data on costs of jet biofuels since there is no scale production in Brazil. Experimental production has taken place, but the costs are unknown. Price policies must be defined and should consider the positive externalities of biofuels.

Box 2: Regional Outreaches

In addition to the 9 programmed workshops conducted in the Sustainable Aviation Biofuels for Brazil Roadmap Project, three Regional Outreach workshops were organized by BOEING with the objective to provide regional views on challenges and opportunities that helped broaden the range of perspectives and stakeholders. EPFL (Victoria Junquera and Sébastien Haye) and 4CDM (Cristiane Azevedo) joined local stakeholders including producers, NGOs, academic experts and public agencies in three workshops. The main roadmap had the greatest concentration of stakeholders (and most of its workshops) from the Southeast region so the Regional Outreaches provided input from three regions: Northeast (Recife), Center-West (Cuiaba) and South (Curitiba). The North Region was not included in the Regional Outreaches due to the fact that it is predominantly composed of Amazonian forest therefore it was not considered a likely candidate for sustainable aviation fuel development.

The major findings and recommendations of the Regional Outreaches are listed below:

FEEDSTOCKS – Explore the potential of feedstocks adaptable to each region such as: Northeast – native palm species (Babaçú – Attalea speciosa, Catolé – Syagrus cearenses, Licuri Palm – Syagrus coronata, and Macaúba Palm – Acrocomia intumescens), castor seed, cotton, oiticica – Licania rígida, other oils, and microalgae; Center West – camelina, cotton, non-edible sweet potato, and soy; South – camelina, castor bean – Ricinus communis, cártamo – Carthamus tinctorius, crambe – Hochst abyssinica, forestry, forrage turnip – Raphanus sativus L., jatropha, macaúba, microalgae, peanut, rapeseed, sunflower, tungue – Aleurites fordii, and woody residues. Very little agronomic information is available for most, so agronomic studies must establish producing guidelines and best practices.

FOCUS – In the short term, focus on medium – to large-sized producers since they can produce at the scale needed.

COLLABORATION – Develop a model enabling structured collaboration between universities, national and state research organizations, government agencies and industry that stimulates innovation and dialogue while minimizing bureaucracy, leveraging capabilities across the country and transferring technologies to industry. Provide mechanisms for funding from national and international investors, as well as government. Drive productivity and regional development with mechanisms such as the "rural extension" program to transfer knowledge of best practices between state agronomic institutes, local Embrapas and research entities.

SUSTAINABILITY – A common definition frames sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." It is critical to address economic, social and environmental aspects of sustainability in developing supply chains for aviation biofuels. It makes business sense to avoid creating unnecessary impacts and triggering controversies over land, water, labor conditions, food prices or deforestation, and to demonstrate long-term financial viability in a world that may be dominated by climate change effects on agriculture. International sustainability standards and voluntary certifications, such as the RSB or Bonsucro, allow producers to demonstrate to their whole supply chain that they are using good practices, giving them an advantage in the market, especially for aviation biofuels, where the buyers are interested in proving the sustainability of their fuel supplies

POLICIES – Establish policies that incentivize and consider the whole supply chain and the biofuels industry as a whole, not policies specific to a particular feedstock or process. Apply smart incentive policies over time, at regional and national levels, to eventually make production economically sustainable. Expand investment in infrastructure, especially road and rail, is a fundamental condition for acceleration of sustainable regional biofuels industries as well as overall development of Brazil.

More details about the Regional Outreach Workshops can be found in Annex 1 of this report.

9.2 Refining Technologies

Current technologies allow conversion of feedstocks to drop-in jet biofuel and following a similar method previously used for feedstock assessment, a multicriteria analysis was conducted on 3rd Workshop ("Refining Technologies"). It also showed that all alternatives have strategic potential to be compliant with the roadmap goals, but, again, technical and commercial risks need mitigation and are somewhat specific to each alternative. **Table 31** lists some of the most important technical and commercial aspects identified. Gaps and barriers summarized and briefly described here.

Sugars and vegetable oils can be efficiently transformed into jet biofuel and the technologies are well known and can be implanted immediately, however both are foodstuffs and not available in sufficient amounts to substitute a large percentage of jet fuel. Furthermore, vegetable oil market prices are following petroleum price developments.

Table 31 Pros and cons of refining technology alternatives.

REFINING TECHNOLOGIES	TECHNICAL ASPECTS		COMMERCIAL/FINANCIAL ASPECTS	
	PROS	CONS	PROS	CONS
Alcohol to jet fuels	• Technology available to be implemented	• Significantly more alcohol may be produced in Brazil (1st generation and may be even more by 2nd gen. technol. • No commercial plant set up yet.	• No expensive equipment necessary • Alcohol in Brazil is currently made from sugarcane (1st gen) and it is planned to be produced also by 2nd gen. technol.	
Direct fermentation of Sugars to Hydrocarbons (DSHC)	• First generation commercial plants exist in Brazil. • DSHC is produced in Brazil from sugar(1st generation and 2nd gen. technol).	• Standard sterilization is required.	• No expensive equipment necessary, however the technology development is expensive	• Alcohol in Brazil is currently made from sugarcane (1st gen) and expected to be soon produced by 2nd gen. technol.
Hydroprocessed Esters and Fatty Acids (HEFA)	• Commercially available	• Needs expensive hydrogen, however integration of this plant to an existing refinery/ power plant would lower costs for the hydrogenation step.	• Efficient process	• Product is expensive due to the high price of feedstocks. Algae and microbial lipids are potentially cheaper (long term).

Table 31 Pros and cons of refining technology alternatives (continued).

REFINING TECHNOLOGIES	TECHNICAL ASPECTS		COMMERCIAL/FINANCIAL ASPECTS	
	PROS	CONS	PROS	CONS
Thermal Cracking of fatty materials	• Cheaper option than HEFA	• Forms a complex mixture of different products	• Can be performed in small plants	• Many different products have to be separated
Fisher- Tropsch	• Available in demonstration plants	• Needs expensive equipment	• Any biomass can be gasified	• Expensive equipment necessary, needs large amounts of carbon-rich feedstocks
Solvent Liquefaction	• Forms bio-oil in a single process	• Needs further research	• Any biomass can be liquefied	• Expensive equipment necessary
Fast Pyrolysis	• Good yields of bio-oil and bio-char	• Needs further processing of the products (i.e. hydrotreating or gasification)	• Any biomass can be pyrolized, can be performed in small plants	• Products need further processing
Acid/enzyme Hydrolysis	• Cellulose available in huge amounts	• The enzymes are expensive and slow	• Forest and agriculture residues available in large amounts	• Hydrolysis is a slow process, needs expensive enzymes and high dilution of feedstock
Industrial Residues Recycling	• Treatment/ reduction mandatory	• Needs further development	• Need to be treated/reduced	• Costs of conversion unknown
Municipal Waste	• No costs of feedstock (short term)	• Expensive separation, availability not known	• Available at negative costs	• Expensive processing
Gases	• Low to negative cost of feedstock	• Low concentration and availability	• Interesting source for hydrocarbons, needs to be treated/reduced	• Costs of conversion unknown
Sewage	• Negative cost of feedstock	• Expensive processing	• Interesting source for hydrocarbons, needs to be eliminated	• Needs further development

Lignocellulosics are available in sufficient amounts to substitute petroleum, however, there are logistic problems – their energy density is too low for transportation on long distances – and the capital investment for gasification or solvent liquefaction is high. Fast pyrolysis may be an interesting option to increase energy density. Mild-acid hydrolysis produces a pentose-rich slurry able to be fermented by robust yeasts to produce lipids. The cellulose rich fraction would be enzymatically hydrolyzed to sugars, followed by fermenting to alcohols (i.e. bioethanol), a well developed and commercially executed around the world; these sugars can also be fermented to lipids and hydrocarbons.

Brazil has a long tradition in producing bioethanol and this biofuel is currently used as a building block to generate poly(ethylene) in a commercial chemical plant, in a similar process used for the ATJ technology. Naturally, second generation sugars would improve the sustainability of sugar derived alternative jet fuel, such as ATJ, DSHC and some HEFA pathways (i.e., algae oil derived from sugar).

Lignocellulosic biomass has low energy content. Therefore, it has to be converted into higher energy materials (bio-oil, bio-char) which can be transported to the hydrotreating and gasification plants. On the other hand, solvent liquefaction can be done in a small scale at the production site of the biomass.

Enzymatic hydrolysis of cellulose is certainly an interesting option. However, the process is still slow and needs substantial improvement to provide good quality hydrolizates to supply the large potential demand for fermented biofuels and up to now, only pilot and demonstration plants were built and all of them show sincere economic problems, i.e. the price of ethanol from these plants is higher than from sugar cane (MOSIER et al., 2005). A commercial second generation plant for bioethanol is expected to lauch in 2013 by Granbio in the northeast of Brazil. Besides this, cheaper and more efficient enzymes are needed in order to make enzymatic hydrolysis economically viable. The improvement of the microorganisms to excrete larger amounts of enzymes, synergistically working, would be very advantageous. It is desirable to have enzymes with higher turnover number and more affinity for their substrates, as increased robustness to biofuel process conditions.

Conversion of vegetable oils to hydrocarbons (HEFA) is commercial, however expensive feedstocks are needed, even though their costs can be shared with other co-products, as soy protein, for instance. The integration of this plant to an existing refinery/power plant would lower costs for the hydrogenation step of the process. Similar technology developed in Brazil by Petrobras (HBIO) is able to produce a similar product, which would allow blending with conventional jet fuel. Optimization of this process is under way. The existence of a Brazilian Biodiesel Program, well established in the market since 2005 and based upon the same type of feedstock, simplifies the economic comparison of feedstock pricing, because they are already competing for the same market. Consequently, the prices of feedstock, after the diverse necessary pre-processing can be considered equivalent, once taking into account the social benefit provisions of the Brazilian Biodiesel Program. In 2011, the country has produced circa 2.5 billion liters of biodiesel, quantity enough, in energetic terms, to more than one third of its jet fuel consumption (LA ROVERE et al., 2011).

Vegetable oils are totally consumed by domestic use for bio-diesel production. To use vegetable oils as a source of jet fuels, the production would need to be increased and then, their price would lower. Another feedstock for hydro-processing would be microbial oils which potentially could be cheaper when second generation lignocellulose technology is available.

Microbial oils (algae & yeasts): Concerning sugar fermentation processes (yeast/algae), the limitations are mostly related to the cost of the first generation sugar and to the low conversion of the overall reaction. It is expected that improvement of metabolic engineering knowledge would help to increase the yield and productivities moving to second and third generation fuels.

Wastes should be used for the production of transportation fuels, however, the quantities available seem to be rather small and the conversion technologies are not always well known.

Conversion of **Municipal waste, sewage, flue gases, industrial residues** by biochemical processes, avoiding therefore the high temperature conditions of the thermochemical processes applied for cellulosic materials, is being developed and not much can be said about commercial viabilities. Clearly, the main gap for solid municipal waste is the separation and fractionation. A new industry dealing with solid waste could be developed in Brazil. This study did not find enough information to answer the costs of conversion into jet fuels for industrial residues, gases and sewage. On the other hand, wastes are often available at null costs and transforming wastes into useful products should be encouraged, even though their future price will increase to reflect their value. More research is required to know the costs of separation and processing of the different constituents, mainly for municipal solid wastes. Conversion of tallow and yellow greases is possible using the HEFA process, but the limited availability and opportunity cost of these feedstocks are driving them to biodiesel production under Brazilian conditions. Financial support for the transformation of lignocellulosics and waste to jet fuel should be available.

9.3 Logistics

Discussions about the logistics of production and distribution of jet fuel in Brazil included, quality control requirements and safety procedures associated with jet fuel handling and the impacts of jet biofuel commercialization on the distribution system. The main stakeholders of the conventional jet fuel distribution chain in Brazil, future jet biofuel producers, airlines association, international specifications boards and Brazilian regulatory agencies participated in the discussion process.

The main aspects of the installed jet fuel logistics and of the necessary adjustments for introduction and commercial use of biofuels are:

1. The logistics of conventional jet fuel in Brazil are well organized. Although consumption is very concentrated in large international airports close to oil refineries, a small fraction goes to regional airports that sometimes can only be reached regularly by air or by water ways during part of the year. Furthermore, some regions of the country are supplied almost exclusively by imported jet fuel. All these important aspects will have to be considered in the implementation of a national policy promoting jet biofuel and, therefore, depending on the adopted model for jet biofuel utilization in the country (if mandatory for instance), these aspects could become barriers, or eventually opportunities;
2. By adopting the international concept of “drop-in” jet biofuel, the essential anticipated barriers for the distribution logistics of the fuel, like recertification of aircrafts, changes of airports infrastructure are surpassed. Even if for the initial experimental steps of using aviation biofuels there may be some impacts in the

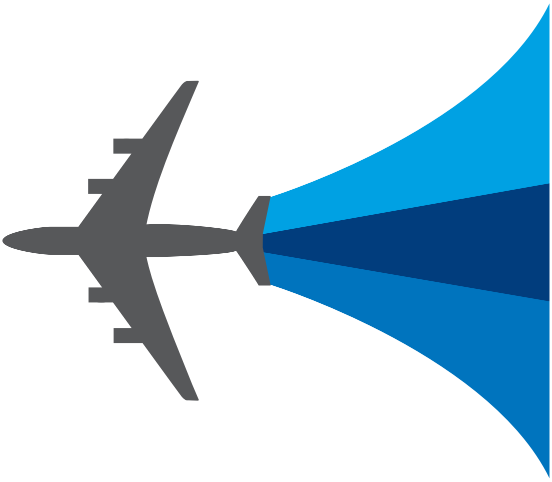
fuel supply infrastructure at airports due to especially dedicated tank trucks, on the long term the biofuels will be blended somewhere else in the distribution chain and will come to the airports simply as jet fuel ASTM D1655, therefore implying no change in the airports infrastructure. Explaining, after approval of the blend according to ASTM D7566, attested by the batch Certificate of Quality, the biofuel is re-identified as satisfying ASTM D1655 and it becomes fungible with any approved jet fuel and subjected to the same requirements as conventional jet fuel. However, some new infrastructure will be needed in the blending point of the distribution chain for commercialization. According with ANP Resolution Nr 20/2013, recently issued, the commercialization of alternative jet fuels is restricted to importers or jet-A1 producers authorized by ANP, and the commercialization of the blends is restricted to jet-A1 producers or distributors authorized by ANP. Therefore, this new infrastructure should occur as part of these businesses. To reinforce this aspect, one should imagine the overall picture of a future jet biofuel distribution logistics in Brazil, keeping in mind that of the 13 largest airports responsible for 85% of jet fuel consumption in the country, 10 are mainly supplied by nearby oil refineries, 2 are supplied through imports by sea (7%) and only Brasilia International airport (6%) is supplied via tank trucks from a refinery 700 kilometers away. Therefore, on the long run, the best alternative for finishing the synthesized paraffinic kerosene and preparing the blend are refineries or terminals nearby important airports. From this blending-point on, the jet fuel containing a certain percentage of biofuel would be using the same distribution chain of the conventional jet fuel;

3. On the other hand, an airport like Brasilia's which consumes approximately 500 million liters of jet fuel a year distant from refineries and close to agricultural feedstock production sites, could economically benefit twice of the high logistics cost in the country by finishing the jet biofuel blend close to the consumption site. However, it is worth to remember that batch certification is expensive for small volumes and, if necessary for the fuel production process, the cost of hydrogen can be lower close to oil refineries. For this step to be taken, one gap to be surpassed is the reduced installed competence in the country to do the necessary quality tests;

4. Because the initial processing of agricultural feedstock should be made nearby the farms for economical reasons, the logistics of the jet biofuel production deserves detailed studies for each type of feedstock and applied processes to maximize economic benefits. Due to the high contribution of logistics cost on the overall cost of the biofuel, this gap deserves special attention;

5. In the future, when there will be different suppliers of jet biofuel and several airlines buying it from the same airport jet fuel pool, the jet fuel received by one airline in its fuel tanks will be just jet fuel ASTM D1655, with or without some percentage of biofuel in it, following the same exact procedures used for conventional jet fuel. The quality control systems and traceability requirements by aviation will be kept the same, based on the physical chain of fuel supply. Therefore, the amount of biofuel bought by one airline, to ensure it is doing its part on the effort to reduce CO_2 emissions, will be demonstrated by emission certificates specific for the aviation sector. Eventual energy benefits of the biofuels will be included in the agreed price and on the effective participation of the airline in the pool. The establishment of specific commerce rules and the respective assurance system is a gap deserving attention in due time;

6. If different excise taxes are applied to renewable and fossil jet fuels to facilitate the penetration of biofuels some future work will have to be carried out together with Federal and State fiscal authorities.



PART III

TECHNOLOGY DEVELOPMENT STRATEGY

10 TECHNOLOGY ALTERNATIVES

10.1 Feedstock

Feedstocks are a crucial element in the production of biofuel for aviation, affecting directly the final cost and environmental impacts. Nevertheless, the Brazilian conditions are particularly attractive for agricultural products in general, and among them, bioenergy. In fact, the variety of options is a challenge, more than the lack of alternatives to explore.

Brazil is a traditional agricultural goods producer and is among the world's leading producers and exporters of many agricultural products such as soybean, sugarcane, coffee, cotton, maize, tropical fruits, meats, etc. This relevant position was attained not only because of abundant land and good climate conditions, but also due to long-term investment in research and development and an entrepreneurial private sector. Thus, Brazil shows currently a favorable combination of availability of land for agriculture not occupied with native vegetation, notably pastures, with a dynamic agriculture sector presenting steady productivity growth, large amount of law protected native vegetation, strong conservation laws based on "control-command" enforcement and human health and safety regulations for rural activities equivalent to urban activities. This remarkable combination places the country, from a feedstock supply perspective, in a good position of developing an aviation biofuel program with compliance with responsibility principles and sustainability requirements.

The agricultural activities, including ranching, occupy 30.4% of the Brazilian territory, while 65% of the territory is covered with native vegetation (**Figure 24**). Law protected native vegetation (conservation units, indigenous reserves and private properties) represents 87% of the total remaining native vegetation. Annual and perennial crops, however, have a small share on the 30.4% of the total agricultural land: only 23% (7.1% of the Brazilian territory) (IBGE, 2013). The majority of the Brazilian agricultural land is occupied with pastures, used mainly for beef cattle production, and the introduction of better ranching practices can open a large area of arable land for agriculture.

The feedstock to be processed to produce aviation biofuels should be primarily a good carrier of solar energy converted in chemical energy. So, biomass material to be used for biofuels can be rich in sugar, starch, fat, oil, fiber and obtained directly or indirectly by cultivated crops, algae or residues, delimiting the conversion processes that can be adopted. Specifically for the production of biofuels for aviation, a large number of feedstocks can be used (and in fact have been proposed), however, important requirements such as capacity to improve yields, low direct and indirect greenhouse gases emissions, high efficiency in land use and positive social and economic impacts also need to be fulfilled. The possible feedstocks can be grouped according to their related chemical affinity:

1. Sucrose/starch rich plants (e.g. sugarcane (juice), sorghum, cassava)
2. Oil-bearing feedstocks (e.g. soybean, palm, jatropha, camelina, green algae, sunflower, peanut, other palm trees)
3. Lignocellulosic materials (e.g. forestry wood residues, sugarcane (bagasse), industrial forestry residues, agricultural residues)
4. Wastes (e.g. CO rich flue gas, municipal solid waste, used cooking oil, tallow, sewage sludge)

Feedstocks usually represent a significant percentage of biofuel production cost. In the case of Brazilian ethanol, sugarcane reaches 70% of overall costs and for biodiesel even 90% (NOGUEIRA, 2013). In the case of jet biofuel, this will depend on the processing costs, but assuming that the cost of new fuel will follow basically the same cost structure after the technologies have been mastered, then typically feedstocks will remain as the most critical cost item in the jet biofuel production. In this regards, is worth to stress that the jet biofuel will only be competitive with a low cost feedstock.

Possibly, the jet biofuel technology will follow a learning process similar to that experienced by the Brazilian ethanol, where a significant cost reduction was observed during the effective development of the market for this biofuel in Brazil, as a consequence of R&D activities and improvements in management and logistics (**Figure 75**). Other important aspects to take into account on feedstocks selection are productivity (e.g. allows to use less land and minimize other related impacts), complementarity (e.g. a certain feedstock may be a good solution for a particular region but there may be other good solutions for different regions) and commercial readiness (e.g. feedstock A may be fully commercial but feedstock B and C may need additional and substantial R&D investments).

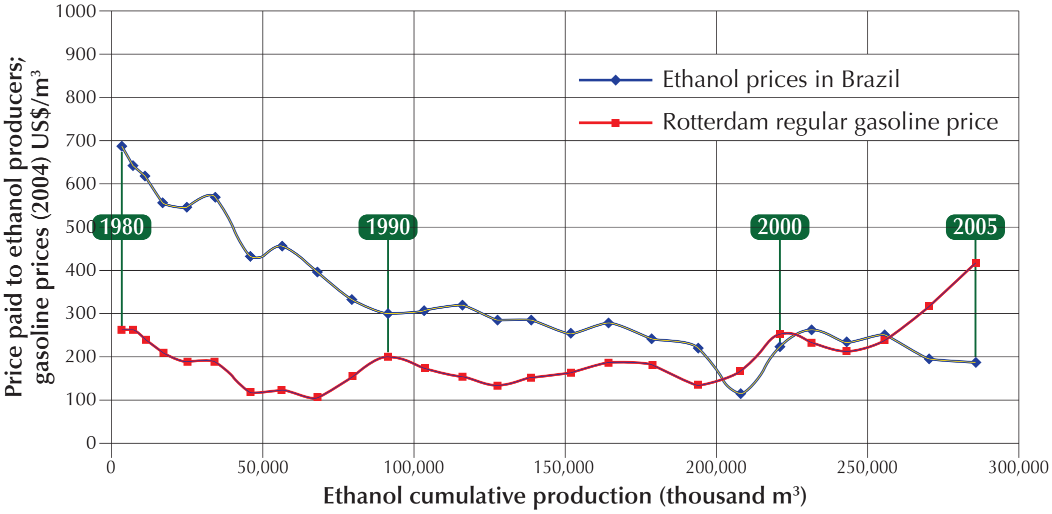


Figure 75 Sugarcane Ethanol Learning Curve. Source: Goldemberg, 2007.

A multi-criteria analysis conducted on 2nd Workshop ("Feedstock") looked at feedstocks according to three broad categories: (i) strategic potential, (ii) technical risks and (iii) commercial risks. That analysis showed that all categories of feedstock alternatives have strategic potential to be compliant with the roadmap goals (**Figure 76**), but technical and commercial risks need mitigation and are somewhat specific to each feedstock being considered, as shown in section **Gaps and Barriers** (**Part II, Table 28 and Table 29**).

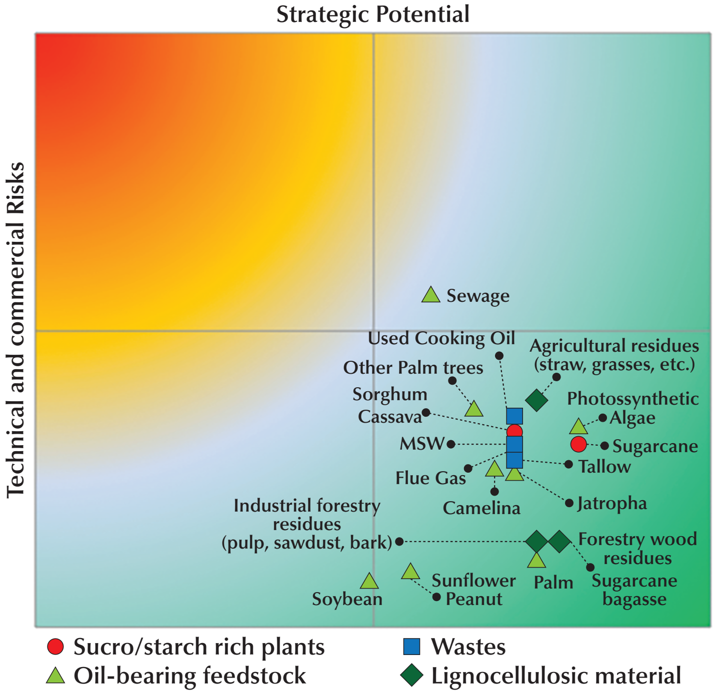


Figure 76 Multicriteria analysis of different feedstock alternatives.

This section is based on the compilation of results of the group discussions in that workshop. The participants were divided in four groups: oil-bearing feedstocks, sucrose/starch, cellulosic feedstocks and wastes. The list of feedstocks analyzed covers a large number of products compared to those addressed in the individual presentations.

The participants scored the feedstocks according to three broad categories: strategic potential, technical risks and commercial risks. Each category was divided in several sub-categories (19) and the score process was based on four or five sets of options.

Table 32 summarizes the results and allows for the classification of the feedstocks according to its strategic potential and technical and commercial risks. Residues from widely produced feedstocks (forestry and sugarcane), from steel and chemical industries (CO rich flue gases) and wastes (Municipal Solid Wastes) were classified at the top of the ranking. Among them, with exception of sugarcane, all other feedstocks are by or co-products of different industries.

Oil-bearing crops, in general, received a lower score, especially because the participants perceive them with high commercial risks. This is coherent with the food security debate and with the fact that oil-bearing crops, in general, have lower energy yields. Sweet sorghum and cassava are in the middle probably because, either they are complementary to other crops (sorghum), or because they are a well-known crop (cassava).

Clearly the participants have scored the feedstocks assuming that by or co-products are better suited for producing biofuels, as well as high energy yield crops (sugarcane). The only exception was the agricultural residues, mainly because of the technical risks associated to collection and transportation.

These remarks should be considered taking into account that the participants in this scoring process were divided according their own experience and expertise, and therefore maybe presented some bias in their assessment, which explains the relative concentration of the scores in the positive region. Even so, the outcome is interesting should be taken by the relative value of each feedstock with regards to the other. Besides, forestry as a source of biomass was not included in this evaluation, but in many senses, it can be considered also an attractive feedstock, at same level of forestry residues, depending on the specie and yield considered, as will be discussed further in this chapter.

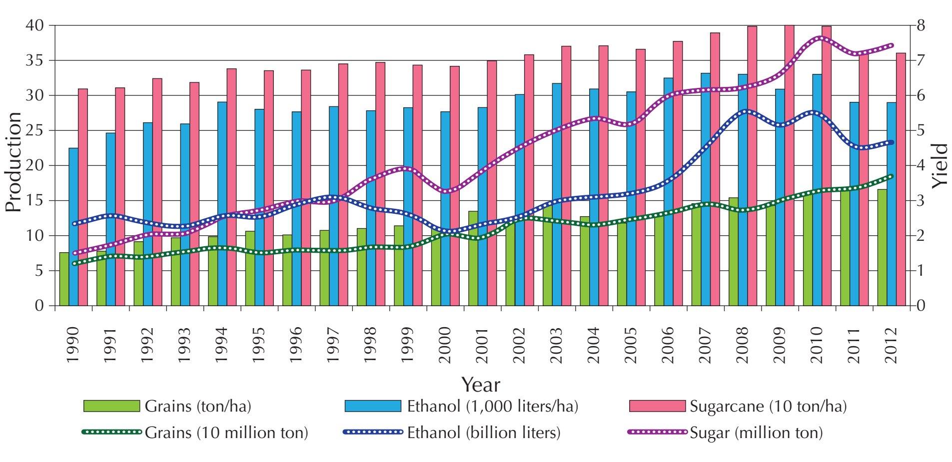
Table 32 Feedstocks classification: strategic potencial, technical risks and commercial risks.

FEEDSTOCK	STRATEGIC POTENTIAL	TECHNICAL RISKS	COMMERCIAL RISKS	TOTAL
Forestry wood residues	3.1	4.0	4.5	11.6
Sugarcane bagasse	3.1	4.0	4.5	11.6
Industrial forestry residues (pulp, sawdust, bark)	3.0	4.0	4.5	11.5
Sugarcane	3.3	4.2	2.7	10.1
Tallow	2.9	3.6	3.5	10.0
Flue Gas	2.9	3.4	3.7	9.9
MSW	2.9	3.2	3.7	9.7
Sorghum	2.9	4.0	2.7	9.5
Cassava	2.9	4.0	2.7	9.5
Used Cooking Oil	2.9	3.2	3.2	9.2
Agricultural residues (straw, grasses, etc.)	3.0	2.6	3.5	9.1
Palm	3.0	4.8	0.5	8.3
Jatropha	2.9	3.8	1.5	8.2
Photossynthetic Algae	3.3	3.2	1.5	8.0
Camelina	2.8	3.6	1.5	7.9
Sunflower	2.3	4.8	0.5	7.6
Rapeseed	2.3	4.8	0.5	7.6
Peanut	2.3	4.8	0.5	7.6
Soybean	2.0	4.8	0.5	7.3
Sewage	2.4	2.0	2.3	6.7
Other Palm trees	2.6	2.6	0.5	5.7
Other Oils	0.9	3.0	0.5	4.4

Box 3: Why indirect effects of biofuels feedstocks are low in Brazil

ILUC and food versus fuel are the two most relevant indirect effects raised as concerns in the biofuels debate. Several evidences indicate that the expansion of biofuels in Brazil have not undermined food production. The same evidences also show that the establishment of cause-effect straight relations between biofuels expansion and native land conversion has no support in the reality. The evidences are based in the following topics:

1. Brazilian agriculture is facing process of intensification and efficiency gains with increasing yields in crops and livestock;



2. There still is a lot of space for intensifying cattle production in Brazil. Technical yields such as slaughter age, calves' birth rate and meat produced per hectare are still low in Brazil.

3. Brazil has developed a double-cropping system allowing the integration of soybean and corn in the same year. The double cropping is already responsible for half of the total corn production in Brazil and since the year 2000 all corn production expansion has taken place as a second crop.

4. The expansion of sugarcane for ethanol, although very strong, has not undermined the expansion of other annual and perennial crops. Therefore, rather than food-versus-fuel, the reality in Brazil shows a food-and-fuel situation;

5. The cultivation of oilseeds in rotation with sugarcane is also generating food and fuel in the same systems.

6. Deforestation rates are being reduced since 2004. Deforestation levels in 2011 and early 2012 have been very encouraging, at around 75% lower than 2004 levels.

Partial conclusions

Brazil has several good options for plant feedstocks for aviation, associated to a large availability of land, water and favorable climate for crop production, however it seems still early to recommend the very best options. Scale of production is an important characteristic, affecting directly the product cost. Some crops are already widely produced because they are well adapted to local conditions, were object of much R&D investment in the past, have good market value and favorable price/cost ratio, and have the support of well-organized supply chains. Being proven for other purposes, these crops are also natural candidates as price-competitive feedstocks for aviation biofuel. Sugarcane and soybean are the main examples which are already used for the production of other biofuels.

Some aspects that may have been overlooked in the discussions and that affect cost, convenience and environmental impact are the capacity of the desired feedstock to be grown in high slope areas without causing excessive erosion (where competition with other food or non-food crops usually is less pronounced), to be able to be harvested in different seasons, and to be stored for long time without the need of immediate processing. Forest or woody species with long cycles are among the plants that meet these requirements. Brazil has large tracts of land with unfavorable slopes for row crops (food competition) but that are suitable for long cycle plants that can be harvested at long intervals, which may offset the problems and costs of operating in hilly landscapes.

Actually, the range of choices is wide. Therefore, the workshop did not focus only on the present success stories and the most obvious options as of today. A central objective of the workshop on feedstocks was to identify the main technological challenges each feedstock is currently facing and the critical variables that determine which technological alternatives should be selected for future developments. The strategy taken was to capture those elements using two approaches: individual presentations and group discussions.

Establishing technology drivers, however, was one of the concerns associated to the workshop. A second one was that a large group of feedstocks should be considered, not only because they have advantages and disadvantages, but also because several refining processes are flexible, accepting different types of feedstocks.

Another objective was to present to the participants the current situation of the feedstocks in terms of production status, alternative uses, level of competitiveness, potential of energy production, and limiting factors for large scale supply. It was expected also to understand the problems and challenges both on production and logistics, given that the localization of the refining facility is strongly affected by the distribution of the feedstocks.

The choice for evaluating several feedstocks was interesting because it made possible to gather a good set of information on several products. On the other hand, it became more difficult to harmonize and standardize the information for cross comparisons and to create classifications of the feedstocks analyzed. Not only the number of feedstocks was large, but also they were different in their nature and usage in the refining processes.

To establish balanced comparison between agricultural-based and non-agricultural feedstocks not necessarily leads to useful conclusions. While wastes such as CO rich flue gas and municipal solid wastes have in principle no problem of supply, they are not easily concentrate to create scale, but agricultural-based feedstocks uses land as main producing resource and might lead to food security concerns. On the other hand, widespread agricultural feedstocks have already available well organized supply chains, as observed in the soybean case, making its use to bioenergy purpose more straightforward.

Despite of the very different nature of the feedstocks analyzed, some consensus lines could be drawn from the ideas raised and discussed in the workshop. There was consensus that by and co-products from agricultural and forestry production are preferable because of the lower impacts on land use and food security, lower opportunity costs and high availability in current conditions. Oil-bearing crops, on the other hand, are available but have lower energy yields and raise concerns on food security. Some innovative oil-bearing crops that are not currently available for commercial production in Brazil, can be produced as a second crop or are able to be grown in degraded land, but the lower energy yields remain a disadvantage.

Crops that can be integrated to production systems taking advantage of the resources already being used were also positively considered. This is the case of sweet sorghum. This is also true for crops with large potential to increase yields such as cassava. Wastes (flue gas, MSW, used cooking oil and tallow) and agricultural residues (straw, trash, leaves) were also considered viable options but collection costs remain high.

At this stage of the aviation biofuel roadmap the recommendation is to consider a wide range of feedstocks instead of selecting a few, although recognizing that some feedstock present currently comparative advantages, such as sugarcane, forestry products and wastes. Depending on the results of research, other alternatives can be incorporated to this list.

10.2 Refining Technologies

Depending on the feedstock, there will be a group of technologies able to process it to the biofuel needed by the aviation industry. In other words, refining technologies are feedstock dependent and as such can be divided into basically in the same groups (**Table 33**).

Table 33 Refining Technologies groups.

Biofuels from sugars	• Alcohol to jet fuels
	• Direct fermentation of sugars to hydrocarbons[14]
Biofuels from oils	• Hydrotreatment/hydrocracking
	• Catalytic Hydrothermolysis
Biofuels from lignocellulosics	• Gasification
	• Solvent Liquefaction
	• Fast Pyrolysis
	• Acid Hydrolysis
	• Enzyme hydrolysis
Biofuels from wastes	• Fermentation to organic acids, to ketone to alcohol, (MSW)
	• Fermentation of CO/H_2 Gases to Alcohol
	• Hydrotreatment of Industrial Fatty Residues

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19 Presently approved and denominated by ASTM as Synthesized Iso-Paraffins (SIP).

Following a similar method used for feedstock assessment, a multicriteria analysis was conducted on 3rd Workshop ("Refining Technologies"), which also showed that all alternatives have strategic potential to be compliant with the roadmap goals (**Figure 77**), but, again, technical and commercial risks need mitigation and are somewhat specific to each alternative, as shown in section **Gaps and Barriers**.

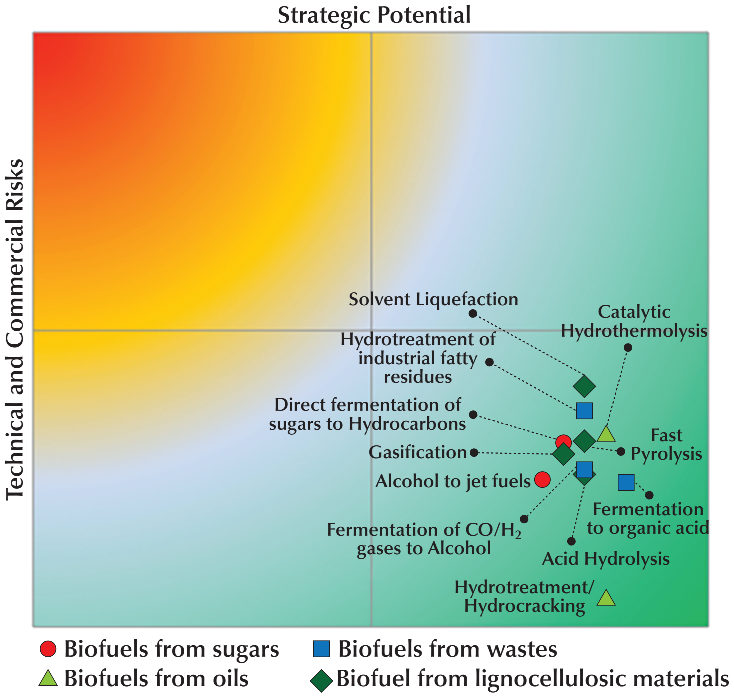

Figure 77 Multicriteria analysis of different refining technology alternatives.

One relevant differencing feature of a given refining technology is its level of development and the matureness. Considering the drop-in requirement and the certification procedure as established by ASTM, some processes for producing aviation biofuels are already available for feedstocks such as vegetable oils and lignocellulosic material (or solid biomass). Process using vegetable oils could be quickly installed as will be detailed in the next section. Another process approved by ASTM, using lignocelluloses to jet fuels needs much more time to be effectively developed. For gasification, pyrolysis and liquefaction, it is expected that at least 10 years are needed for further development. Process involving hydrolysis needs the development of pre-hydrolysis treatment, maybe possible in an industrial scale in more 5 years. However the alcohols produced from the fermented hydrolyzed biomass have to be transformed to jet fuels by chemical processes. Although the transformation of waste to jet fuel is promising, nothing is ready for implementation. In fact, for all technologies, improvements and scale up are still required in order to reduce capital and operation costs and increase reliability.

No preference should be given to any technological alternative. All of them are in principle valid to produce jet biofuel. However at the present conditions, none of the technologies can produce jet biofuels at market price. It is mandatory that the technology to be chosen can produce the cheapest jet fuel, which depends on the selected feedstock and its processing costs.

Conclusions

1. although with very different level of maturity, essentially all the presented technologies have potential for feasibility;
2. if in a short term a mandate for aviation biofuel were settled in Brazil, the quickest technology to be implemented would probably be based on vegetable oils to jet biofuel;
3. cellulosic residues and wastes are very cheap and their transformations by thermochemical or biochemical processes into jet biofuel are potentially very attractive. However, it is advisable to get more qualified data to have a more safe assessment;
4. it is expected that an efficient enzymatic hydrolysis of cellulose and a proper conversion of resultant sugar to jet biofuel can be a solution in a short to medium time period;
5. gasification of lignocellulose is also a very important alternative and jet biofuels could be obtained from synthesis gas for reasonable price within 5 to 10 years;
6. pyrolysis of celluloses is a third important option to make jet biofuel but more development is needed. Several patents have been filed to protect different aspects of process to obtain jet biofuels. It is difficult to analyze the level of conversion yields from the renewable feedstocks up to the final jet biofuel, since property rights usually protect these data
7. it is not easy to find data on the refining of the fractions of fuel that can be directly used or the necessary blending with conventional jet fuel or mixing with fossil additives, in order to accomplish the final specification;
8. each process, from the raw material to the aircraft filling, is composed of different operations, each of them need to be developed, adjusted, optimized and finally integrated to the others. Combinations of those will be needed to lead to the best technologies to produce renewable drop in jet biofuel;
9. a perfect scenario would be a combination of waste feedstock and well developed cheaper conversion process. However it, seems that in short term, only the sugar fermentation to ethanol and ethanol conversion, as well as hydrogenated esters and fatty acids will be suitable for jet biofuels production. For medium and long term, second generation technologies, processing cellulosic biomass may become economically more feasible.

10.3 Identified Pathways

After discussing the feedstocks and refining processes for producing renewable jet biofuel, multiple possible pathways were identified during the project. Certification requirements for regular use in commercial aviation are established internationally according to ASTM D7566 standard, which contains one specific annex for each approved alternative jet fuel production process. **Figure 78** presents an overview of all identified pathways pertinent to Brazil, including the denomination and status of the ASTM approval process. As depicted, two of the final alternative jet biofuel production processes are already approved (green boxes in **Figure**

78) and several others are still under evaluation in the D.02.J0.06 Emerging Turbine Fuels Committee[20].

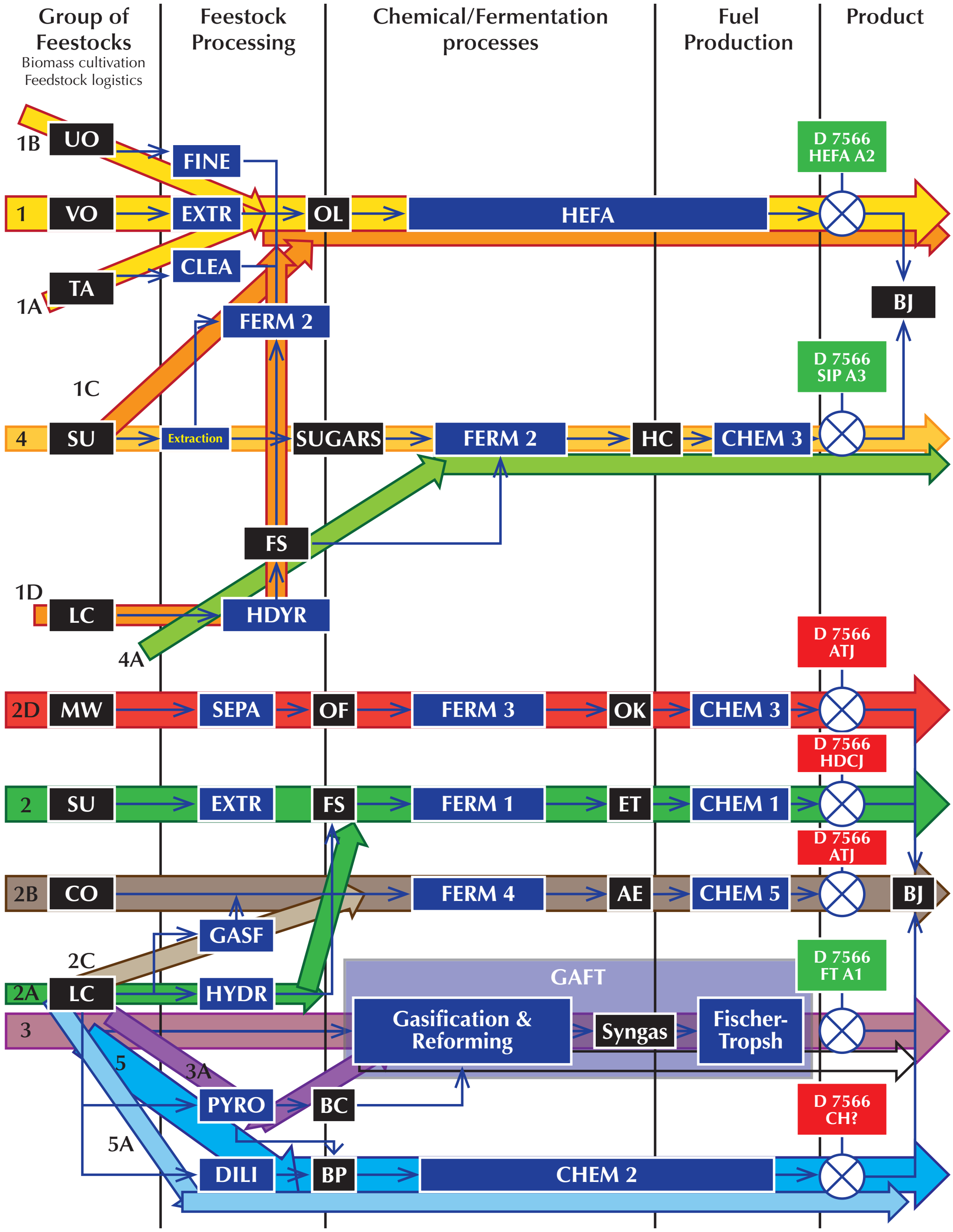

Figure 78 Identified pathways for the production of sustainable jet biofuel in Brazil.

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[20] Since June/2014, the route denominated here as DSHC was approved by ASTM as Annex 3 with the name Synthesized Iso-Paraffins (SIP), for up to 10% blend.

In general after pretreatment, the possible feedstocks are submitted to different conversion processes grouped in three categories: chemical processes for lipids, biochemical and thermochemical processes for other biomasses. The final jet biofuel production processes are usually oil-refinery-like processes to adjust the specification.

While lipids and thermochemical conversion processes have already some routes approved by ASTM, the various biochemical conversion routes still require approval. These processes are briefly discussed in the next paragraphs.

Correspondent Index is presented below (**Table 34**).

Table 34 Index of abbreviations used in the identified pathways.

1. Material streams	**2. Processes**
1.1 Precursors/Feedstock	**2.1 Preparation and Initial Processes**
LC = Lignocellulosic Biomass	HYDR = hydrolysis (acid and biochemical) of polysaccharides to simple sugars
MW = Municipal Solid Waste	PYRO = pyrolysis process of lignocellulosic biomass to bio-oil and bio-char
SU = Sucrose/Starchy Feedstock	DILI = direct liquefaction of cellulosic biomass to bio-oil
TA = Tallow/Yellow Grease	SEPA = separation process of organic fraction from municipal solid waste
UO = Used Cooking Oil	EXTR = extraction process of vegetable oils, of sugars or starches from agricultural products
VO = Oil-Bearing Feedstock	FINE = filtration and neutralization processes of used cooking oil
1.2 Intermediates	CLEA = cleaning, rendering and preparation of tallow
AE = Acetate and Ethanol from Process FERM5 (bellow)	**2.2 Intermediate Processing (conversion)**
	FERM1 = fermentation of sugars/starch to ethanol and other alcohols (conversion of primary feedstock to alcohol intermediates)
BP = Pyrolytic Bio Oil	FERM2 = fermentation of sugars to oils and lipids
BC = Pyrolytic Bio Char	FERM3 = fermentation of organic materials to organic acids
BO = Bio Oil from direct liquefaction of cellulosic materials	FERM4 = fermentation of CO rich flue gas in ethanol and other alcohols
	FERM5 = fermentation of sugars to hydrocarbons
CO = CO rich Flue Gas	GASF = gasification
ET = Ethanol and other Alcohols	**2.3. Final Processing/Refining**
FS = Fermentable sugars	CHEM1 = chemical processes to convert alcohols to jet fuel (dehydration, oligomerization and hydroprocessing)

Table 34 Index of abbreviations used in the identified pathways (continued).

OK = Organic Acids and Ketones	CHEM2 = chemical processes to convert pyrolytic bio-oil in jet fuel (hydroprocessing and fractionation)
OL = Oils, Lipids	CHEM3 = chemical processes to convert specific hydrocarbons in jet fuel
HC = Hydrocarbons	CHEM4 = chemical processes to convert organic acids through ketones and alcohols in jet fuel
OF = Organic Fraction of Municipal Solid Waste	CHEM5 = chemical processes to convert alcohols from FERM4 in jet fuel
1.3. Final product	**2.4. Integrated Processes**
BJ = Jet Biofuel (ASTM spec)	GAFT = gasification+Fischer Tropsch process (and similar)
	HEFA = hydrogenation of esters and fatty acids

10.3.1 HEFA (Hydroprocessed Esters and Fatty Acids)

Sometimes also called HRJ (hydroprocessed renewable jet) are produced by “refining” natural oils much like petroleum is refined today. Hydroprocessing natural oils (plant, microbial oils or animal fats) involve converting these oils from lipids to hydrocarbons through the addition of hydrogen (**Figure 79**, 1 and 1A). The first step converts the lipids to fully saturated hydrocarbons, or synthetic paraffins, by saturating oxygen bonds and double-carbon bonds with hydrogen. These hydrocarbons are then selectively cracked and isomerized to produce primarily diesel, jet fuel, and propane. This process can be integrated into existing fossil fuel refining facilities and operated at similar costs to petroleum refining. They can also be added on to first generation biodiesel production facilities, or built from scratch in stand-alone refineries. The sub-routes are the utilization of residues like used cooking oil (1B), or the industrial sub-products tallow and yellow greases (1A). 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.

Gaps

HEFA fuels are ASTM certified for commercial use in up to a 50/50 blend with conventional jet fuel. The existence of a Brazilian Biodiesel Program, well established in the market since 2005 and that is based upon the same type of feedstock, simplifies the economic comparison of feedstock pricing, because they are already competing for the same market. Consequently, the prices of feedstock, after the diverse necessary pre-processing can be consider equivalent, once taking into account the social benefit provisions of the Brazilian Biodiesel Program. In 2011, the country has produced circa 2.5 billion liters of biodiesel, quantity enough, in energetic terms, to more than one third of its jet fuel consumption (ANP, 2012). Investment cost for hydro-processing is considered to be low, but the cost of common raw materials can represent more than 70% of total cost (NOGUEIRA, 2011).

Other possibilities of feedstock are the microbial lipids, produced by fermentation of cianobacteria, algae or yeasts. They can be accumulated inside the cells after direct fermentation of sugars, i.e. sucrose and glucose (1C) or obtained by fermentation of the soluble sugars from lignocellulose hydrolysates (1D). The economical possibilities of these microbial pathways are strongly dependent on the price ratio of sugar or ethanol to vegetable oils. One relevant aspect is the stability of the transgenic yeast/algae, which has to be improved in large reactors. Commercial risks will be only reduced when cellulose can be used as feedstock. These technologies are available to produce lipids from direct sugar and pilot plant will benefit from second generation of sugars.

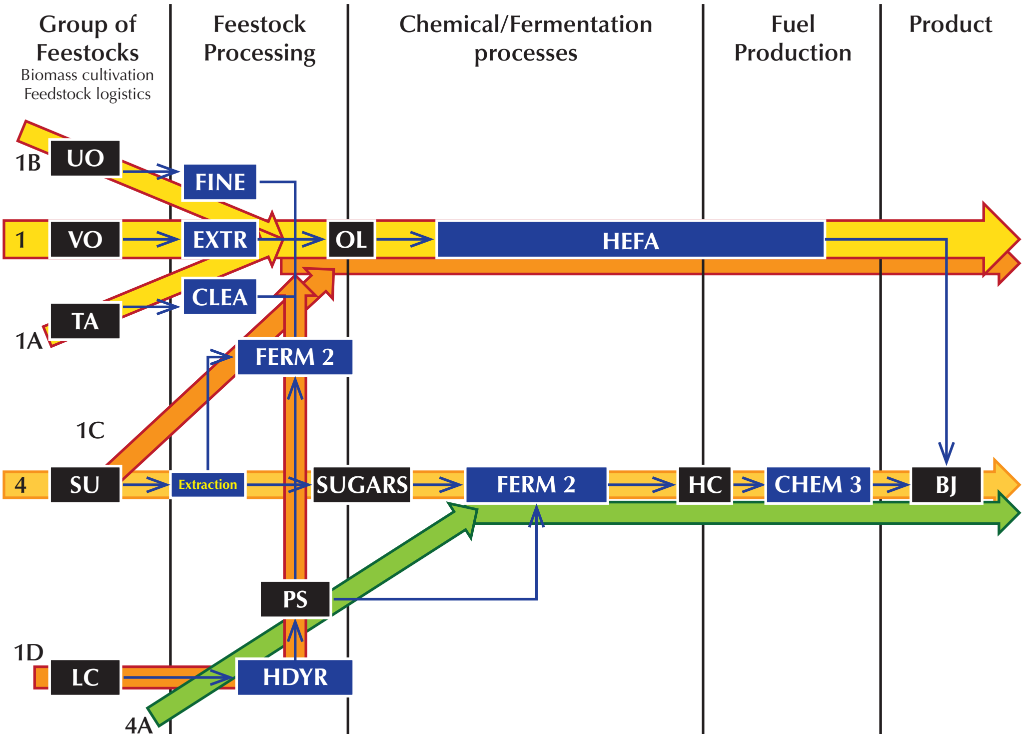

Figure 79 From biomass to HEFA jet biofuel or Solazyme (transgenic algae – lipids).

10.3.2 ATJ (Alcohol to jet)

ATJ (Alcohol to Jet) is made via alcohol oligomerization which involves linking short-chain alcohol molecules (e.g. ethanol or butanol) together to form jet-fuel range hydrocarbons. There are several chemical processes that can be employed to oligomerize alcohols. In each of these processes, water and/or oxygen are removed from the alcohol molecules, and hydrogen is added. Because the starting alcohol volume is reduced in order to produce a marginally more valuable hydrocarbon jet fuel (at current market prices), the economic rationale of these conversions must be critically examined on a company-by-company basis.

Research has been developed using catalysts for the direct and high-yield conversion of bio-ethanol to isobutene, a widely used intermediate chemical used for the production of fuel additives, rubber and solvents. The catalyst requires the presence of water, allowing producers to use dilute – i.e., less expensive – bio-ethanol rather than having to purify it first, potentially keeping costs lower and production times faster. Other methods also have been described by the literature. With increased availability and reduced cost of bio-ethanol, conversion of this particular bio-based feedstock to highly valuable fuels and chemicals has been an especially important research goal.

The original feedstocks for this route are starches or sugars (**Figure 80**). Other alternatives include lignocellulosic biomass, industrial waste gases and municipal solid waste. Starches and sugars may be converted to alcohols through direct fermentation (2). Industrial waste gases rich in CO can be converted to alcohols by gas fermentation (2B). Lignocellulosic biomass may be converted to alcohols by hydrolysis of polysaccharides to simple sugars, followed by fermentation (2A), or by gasification to produce gas (CO + H_2), that can be converted to alcohol by gas fermentation according (LANZATECH, 2012). After separation, the organic fraction of municipal solid waste can be fermented to carboxylic acids that are transformed in ketones that are hydrogenated to secondary alcohols (2D).

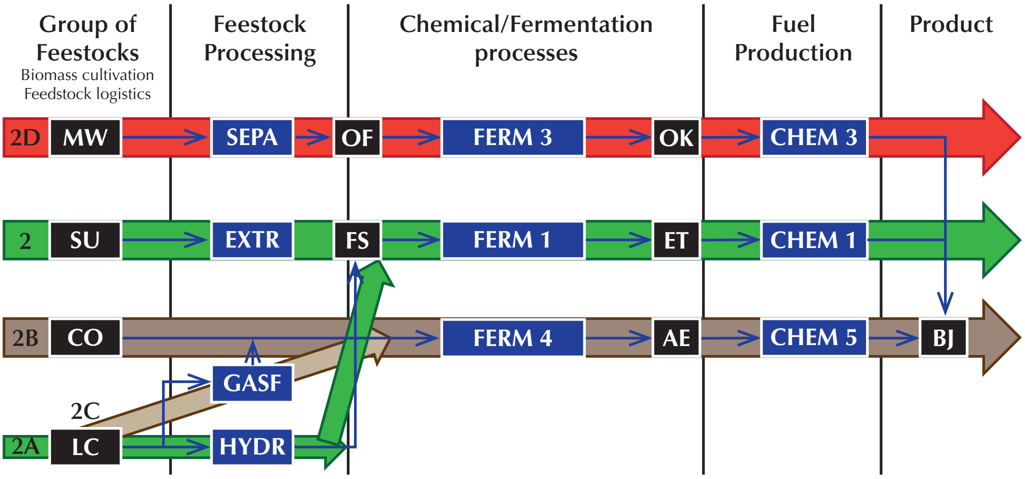

Figure 80 Conversion of sugars (SU), carbon monoxide (CO) and lignocellulose to jet biofuel.

Gaps

Currently, research on bio-ethanol conversion to value-added chemicals focuses mainly on ethanol dehydration to ethylene, or ethanol dehydrogenation to acetaldehyde and then to acetone via Aldol-condensations pathways (SUN et al., 2011). This route, which is in the process of approval by ASTM, requires two principal conversion steps: the conversion of feedstock to alcohols and; the conversion of alcohols to jet fuel. Although the ethanol production from sugarcane by the conventional process has been improved and presents economic competitiveness compared with automotive fossil fuels, the second step is still in development.

No important technical problems have been described for this technology. However, such oligomerization process still needs technical improvements to reduce the competitive gap with conventional jet fuel. Possibly when cellulosic sugar will be available, the commercial risks will be reduced. The alcohol intermediates may be ethanol, butanol, isopropanol, other alcohols, or mixed alcohols. Alcohols are then converted to jet fuel using standard chemical processes. However, the development of more selective catalysts which would convert the alcohols more efficiently to jet biofuels is needed. Due to the large Brazilian experience in producing ethanol from sugarcane and the existence of a well-established agro-industrial sector dedicated to the subject, the natural reference prices for liquid biofuels and lignocellulosic concentrated biomass probably will be ethanol and sugarcane bagasse. Worth mentioning that the ethanol consumption in Brazil in 2010 was approximately 25 billion liters, amount that, in energetic terms, is more than two times the whole aviation fuel consumption in the same year (ANP, 2012).

10.3.3 Syngas/Fischer-Tropsch technologies

The synthesis gas (CO and H_2) is converted into hydrocarbons by growing the carbon chains, usually catalyzed by metal supported catalysts (heterogeneous catalysis), according to reaction (1).

$$CO + 2H_2 \rightarrow CH_2 + H_2O \tag{1}$$

The product obtained by the Fischer-Tropsch reaction is a mixture of hydrocarbons with chains of different sizes, from light gases to high molecular weight greases (Luque et al., 2012; Klerk, 2011). The distribution of the products is a Gaussian type, allowing to be adjusted according to the desired product. In order to achieve commercial specifications for fuels, the liquid mixture of hydrocarbons obtained must be appropriately separated, and as required by the market, also suffer conversion for cracking molecules of high molecular weight into lower molecular weight hydrocarbons or adding other compounds (derived from traditional oil refining) to assist in adjusting the properties required for the specified fuel. Fischer-Tropsch paraffinic kerosene can be produced from lignocellulosic biomass through gasification followed by gas cleaning and synthesis over appropriate catalysts. The process (**Figure 81**, 3) is approved by ASTM for blending up to 50%.

Gaps

Although the cost of the raw material in the field can be very low, the transportation cost is important and limits the size of the processing plant, with large implications on investment cost. Another possible route using lignocellulosic biomass is to start with pyrolysis, obtaining bio-oil and bio-char, intermediate products that could be transported economically through longer distances, to be then submitted to gasification and synthesis by the Fischer-Tropsch process (3A). The current capital cost for the FT alternative is given as high (1€/l for a 200 million liters/year production plant capacity) (MANIATIS et al., 2011). The organized industrial sector that is been considered as a possible supplier of the lignocellulosic biomass is the sugarcane sector, which would pyrolyse the bagasse to bio-oil and bio-char, which can then be transported to the much bigger gasification unit.

The cost of the process is still considered high due to the very special conditions required by the reactions (high temperature and pressure), low density of the biomass, logistic and transport. However, as shown in The Republic of South Africa, the cost of the reactor reduces considerably with increasing size of the reactor.

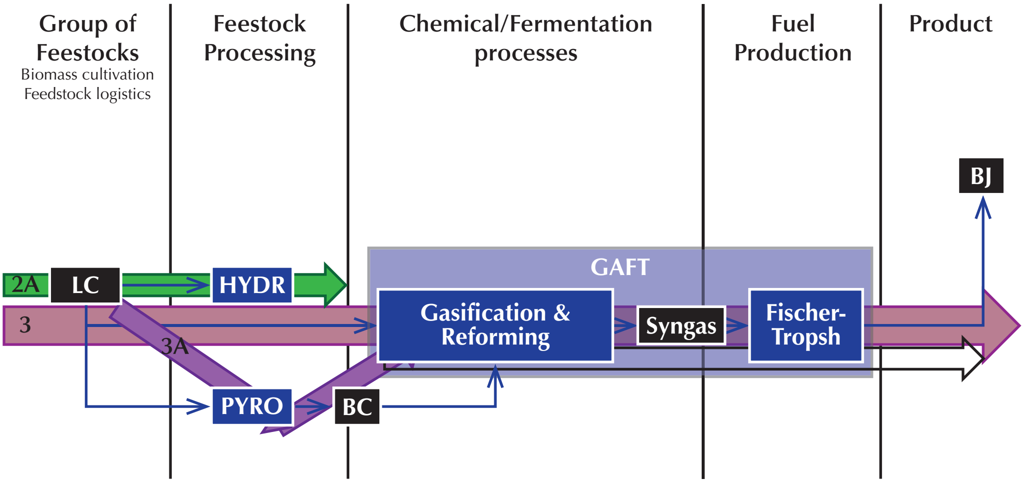

Figure 81 Production of liquid-fuels from biomass via Fischer-Tropsch.

Another possibility is using the synthesis gas for the production of dimethyl ether (what is being done in the demonstration plant at KIT, Karlsruhe, Germany) and then oligomerize and deoxygenate the dimethyl ether to hydrocarbons in the range of jet fuel.

10.3.4 DSHC (Direct fermentation of Sugars to Hydrocarbons)[21]

Some very interesting developments in the area of synthetic kerosene come from metabolic processes of genetically modified micro-organisms to generate hydrocarbon fuel. The principal feedstock for the micro-organisms has been sucrose (**Figure 78**), 4), even though an alternative is to start with lignocellulosic biomass submitted to hydrolysis to obtain fermentable sugars (4A). One of the characteristics of these metabolic intermediates is that they tend to have a very specific chemical identity, with very narrow distillation curves. So the certification challenge for this new route will be in the precise definition of how far one can stand from the broad distillation range of the actual jet fuel, in a way that the renewable fuel can be a ‘fit for purpose’ jet fuel.

The feasibility of materials and energy-dedicated vegetables to be efficiently biologically converted into biofuels with higher added value depends on the capability of microorganisms to use pentoses besides the hexoses, and to stand the most common impurities originated from them. Carbohydrates can be converted into biofuels, as the monosaccharides glucose, xylose and arabinose. Today, the dominant cost factor in biofuel and commodities is the raw material; however several agricultural crops offer non edible wastes, i.e. corn cobs, wheat and rice straw and sugarcane bagasse. Easy transport, short distances and strong logistics allow the employment of suitable treated sugarcane bagasse as for feedstock. The direct sugars to hydrocarbons (DSHC) process, developed by Amyris is a high performing process, already in demonstration plants (5000 L) and planned to be scaled up to 200-600,000 L (AMYRIS, 2012). The sugar cane juice is evaporated and fermented in a closed and aerated bioreactor by a recombinant yeast. Then the excreted farnesene is separated from the broth

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[21] DSHC was approved by ASTM as Synthesized Iso-Paraffins (SIP).

and purified. Farnesene is hydrogenated to farnesane by introducing 4% of its mass in H. The industry is also developing another process in order to obtain a 10 carbon chain biofuel.

Gaps

The current yield is relatively low and should be improved; for the production of 1kg of farnesane, at least 5 kg of sugar is needed. This makes the Amyris Jet Fuel quite expensive at the present sugar price. Thus, the success of this path will also depend on production of cellulosic sugar at low cost.

10.3.5 HDCJ (Hydrotreated Depolymerized Cellulosic to Jet)

Hydrogenated pyrolysis oil kerosene is based on the pyrolysis oils from lignocellulosic biomass (**Figure 82**, 5). Pyrolysis oils can be hydrotreated either in dedicated facilities or co-processed with petroleum oils in refineries. Today pyrolysis oil is at the edge of research towards demonstration level. It is expected that the upgrading of pyrolysis oils will use existing refinery infrastructure, what would make it more competitive than FT. An alternative route to convert the cellulose and hemicellulose from biomass is an aqueous process to furan-derived bio-oil, relying on chemical reactions catalyzed in ionic liquids. The transformation of the bio-oil in jet biofuel is done by deoxygenation processes (5A).

Gaps

The deoxygenation of bio-oils needs drastic conditions. Specific catalysts and expensive hydrogen are needed. It is an area of extensive research, however, up to now no efficient process is available.

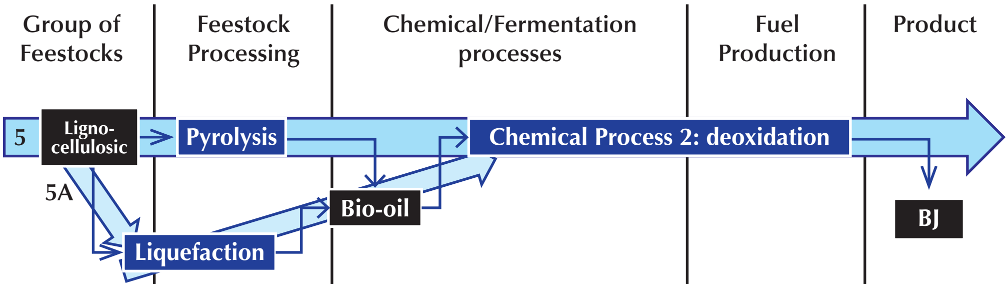

Figure 82 Production of liquid-fuels from biomass via fast pyrolysis or liquefaction.

10.3.6 Final comments on gaps

Due to existing Brazilian programs for promoting the use of renewable fuels for road transportation, the production of jet biofuel will have to compete for feedstocks presently utilized for biodiesel production or ethanol. As the processes to obtain a “drop-in” jet biofuel are more expensive than the processes for first generation ethanol or biodiesel, and because the energy price of jet fuel is usually not higher than gasoline or diesel energy prices, some kind of premium will have to be incorporated to make the production of jet biofuel economically viable. There is potential to expand the production of agriculture feedstocks in Brazil, but certainly their prices will tend to be connected to the prices of other agriculture commodities. Sugars will have to be produced from cellulose and lignocellulosics to make them available in larger amounts and at a compatible price. The conversion technologies of lignocellulosics (enzymatic hydrolysis, gasification and pyrolysis) are available, however there is no demonstration plant of these technologies at present in Brazil[22].

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[22] See 6.1.1.3 and II.5.2 for recent developments on the implementation of enzymatic hydrolysis in Brazil.

RECOMMENDED TECHNOLOGIES

11 ANALYSIS OF IDENTIFIED PATHWAYS

The previous sections presented an overview of the main findings from previous workshops, more specifically 2nd, 3rd, and 4th workshops concerning feedstock, refining technologies and sustainability issues. Those findings provide a wide variety of technical and commercial issues that may lead to the identification of R&D and commercialization gaps. Each of the identified pathways was object of discussion in 7th Workshop, in order to identify R&D needs and commercialization gaps.

In the first place, technical issues in each pathway can be broadly defined in terms of:

(i) the probability to develop a strong and protectable patent, or to develop a proprietary position in the technologies relevant to that specific pathway (Technical Criterion #1: Intellectual Property);

(ii) the probability that the technical resources available may have the capabilities needed to develop a successful pathway (Technical Criterion #2: Capabilities);

(iii) the pathway's technical complexity impact on its success probability (Technical Criterion #3: Technical complexity);

(iv) the effect of external technologies availability and the effect of organizational skills to use such technologies in the pathway's probability to meet its goals (Technical Criterion #4: Access and efficient use of external technology) and;

(v) the probability that an organization (or a group of organizations in the Brazilian aviation industry) has the capabilities (internal and external) to manufacture the product ("drop in" sustainable jet biofuel) or incorporate the production process to its operations (Technical Criterion #5: Production capacity).

In the second place, commercial issues in each pathway can also be broadly defined in terms of:

(i) the probability of existing a market ready for the product, or a big need for the process that results from the pathway in question (Commercial Criterion #1: Market/customer needs - internal or external);

(ii) the probability of the product – "drop in" sustainable jet biofuel – being accepted in the market due to market forces and/or brand recognition in the market of interest – aviation industry (Commercial Criterion #2: Market/business recognition);

(iii) how easily the product will be introduced and made available to customers in the market (Commercial Criterion #3: Channels);

(iv) the probability of success/failure based on customer strength in the business area of interest (Commercial Criterion #4: Customer strength);

(v) the effect of supply and or availability of essential components or materials in the pathway's probability of success (i.e.: feedstock availability) (Commercial Criterion #5: Raw materials or essential components supply); and

(vi) the probability of health, safety and environmental issues affecting the pathway's success (Commercial Criterion #6: Safety, health and environmental risks).

Moreover, an assessment of financial issues complemented the commercial aspects of each pathway, in terms of the probability that the economic agents will receive financial rewards, considering market value, profit margins, typical time it will take to start profiting (positive margins) and, specially, investment (capital expenses and operational expenses) and corresponding financial risks.

Finally, each pathway has a specific potential to comply with the roadmap's vision and goals. Aspects considered in sustainability involved: low land use, promote rural development, low water use, no harm to air quality, maintain or improve 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: environment, social and economics. However, a pre-requirement and "**raison d'être**" of the *Sustainable Aviation Biofuels for Brazil Project* is to evaluate how sustainable biofuels can contribute to mitigate CO_2 emissions. Therefore, low CO_2 emissions with high potential reduction can be considered a pre-requirement or "**sine qua non**" condition.

This assessment, naturally, depended on the focus or perspective from which the biofuel was evaluated. For example, if the evaluation is being conducted for cost analysis, each step of production and distribution needs to be quantified. It is well known that in general the feedstock cost plays an important role in biofuels production. In case of sugarcane ethanol it can be close to 70% and in case of biodiesel up to 80 or 90%. Another perspective, actually the main objective of the *Sustainable Aviation Biofuels for Brazil Project*, is to analyze the proposed biofuel (feedstock and refining technology) from the CO_2 emissions perspective. In this case the entire LCA will need to be performed to analyze its CO_2 mitigation potential and where the main questions to be answered remain.

In sum, the assessment made more visible the areas in need of more research. During the two days of 7th Workshop, specialists were invited to participate in panels to present their views on what are the R&D and commercialization gaps in each of the four groups of feedstock alternatives: sugars, oil bearing, lignocellulocics and wastes.

The second day of this workshop also included a group discussion to perform a multicriteria analysis of each of the identified pathways for biofuels for aviation in Brazil. The audience was divided in four groups, according to the four feedstock alternatives, and each will begin the multi-criteria analysis of potential strategic impact of each pathway, followed by technical risks and commercial risks and financial rewards, ending with an overall discussion of pathways considering feedstocks and refining technologies.

The purpose of the multi-criteria analysis was to gather specialists and foster a fruitful discussion on what are the key issues in terms of R&D and commercialization gaps that should be brought to attention in this roadmapping process. Each group had a facilitator and an editor. The facilitator's role is to support everyone to do their best thinking and practice, encourage full participation, promote mutual understanding and cultivate shared responsibility (KANER et al., 2007). His/her deliverable was to reach an answer for each question, according to a printed template and time constraints and to present a synthesis of the group's discussion. The editor's role was to identify important issues being discussed by the group in each criteria, and his/her deliverable was a written summary of groups discussions, according to a printed template, including rationale for each answer, points of divergence, knowledge gaps in the group, disruptive technologies and future decision points any other observations.

That analysis showed that all identified pathways have strategic potential to be compliant with the roadmap goals (**Figure 83**), but technical and commercial risks need mitigation and are somewhat specific to each combination of feedstock and refining technologies being considered, as shown in previous sections of this report.

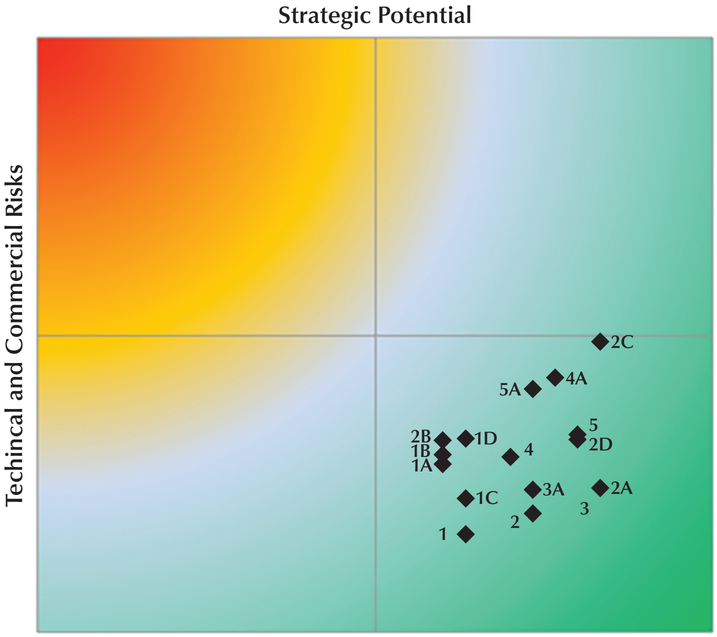

Figure 83 Multicriteria analysis of different identified pathways.

Figure 84 presents an overview of all identified pathways pertinent to Brazil, including the denomination and status of the ASTM approval process. As depicted, three of the final jet fuel production processes are already approved (green boxes in **Figure 84**), including the last one in June/2014 denominated SIP Annex 3. This figure contains essentially the same pathways and intermediary products previously presented in **Figure 78**, and that were discussed in detail in Section 1.3. With the rearrangement it was possible to group the conversion processes into “Lipid”, “Biochemical” and “Thermochemical”, besides highlighting the products and writing down the name of the processes, bringing more information in a cleaner picture. It was also possible to include the catalytic hydro-thermolysis route and to detach a special box for phototrophic algae as feedstock for production of cellulosic biomass or oils.

Table 35 Pathways submitted to multi-criteria analysis.

1	Oil-bearing plants through HEFA
1A	Tallow and fats through HEFA
1B	Used cooking oil through HEFA
1C	Sugar-bearing plants through fermentation to lipids and HEFA
1D	Ligno-cellulose through hydrolysis to sugars to lipids and HEFA
2	Sugar-bearing plants through fermentation to ethanol and ATJ
2A	Ligno-cellulose through hydrolysis to fermentable sugars to alcohols and ATJ
2B	Flue gas (CO, CO/H_2) through fermentation to alcohols and ATJ
2C	Ligno-cellulose through gasification to CO/H_2 to alcohols to ATJ
2D	MSW through fermentation to organic acids to alcohols to ATJ
3	Ligno-cellulose through gasification&reforming to syngas to FT
3A	Ligno-cellulose through pyrolysis to biochar&bio-oil to gasification to syngas to FT
4	Sugar-bearing plants through fermentation by GMO to hydrocarbons (DSHC)
4A	Ligno-cellulose through hydrolysis to sugars to hydrocarbons (DSHC)
5	Ligno-cellulose through fast pyrolysis to bio-oil via deoxigenation (HDCJ)
5A	Ligno-cellulose through direct liquefaction to bio-oil via deoxigenation (HDCJ)

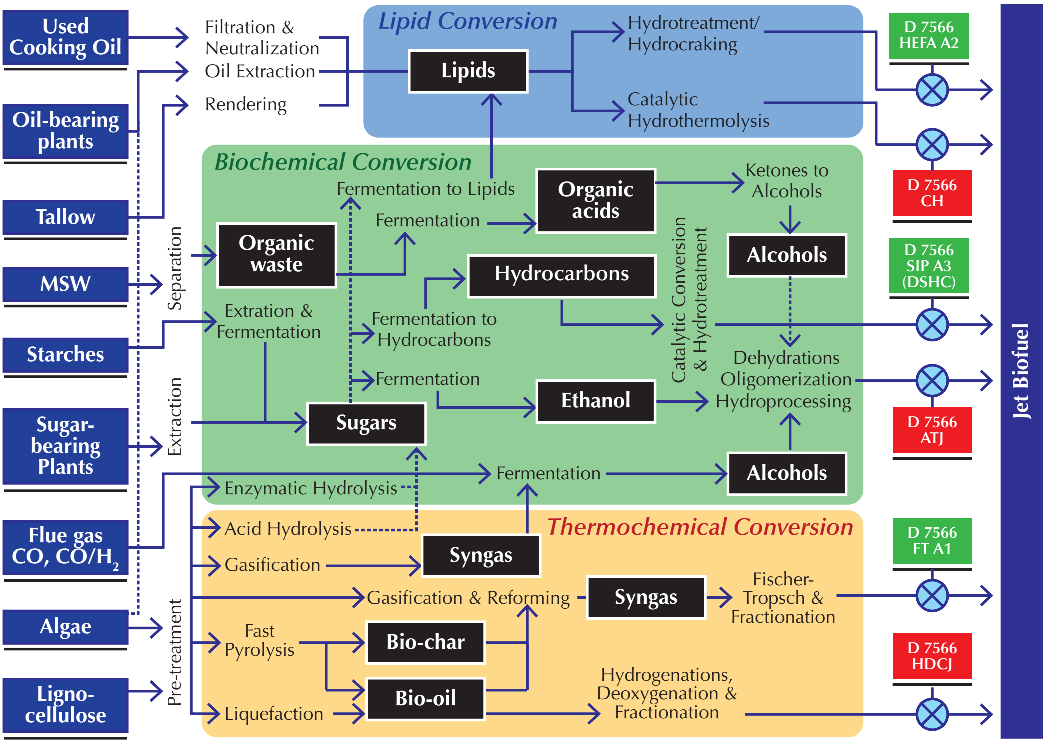

Figure 84 Identified pathways for the production of sustainable jet biofuel in Brazil.

R&D for Identified Pathways

The lipid conversion route is well established and approved by ASTM as HEFA – hydro-processed esters and fatty acids. Investment cost for hydro-processing is considered to be low, but the cost of feedstocks can represent more than 70% of total cost (EC, 2011). The availability of inexpensive hydrogen can affect significantly the final cost. The main gap in this case is a commercial one. The Brazilian Biodiesel Program competes for the same feedstocks – plant oil, tallow and used cooking oil. Eventual niche markets for supplying airports distant from refineries but near agriculture fields could be promoted by the production of hydrogen from biomass, aspect that needs to be better developed in Brazil. The high oil productivity of palm has to be better explored for the Brazilian conditions and R&D on its agriculture side needs to be incentivized. R&D on other oil producing plants can help to improve agriculture gains on lands that are not presently used for agriculture, but it is necessary to treat Brazilian biofuels in an integrated way to avoid the competition for feedstock between jet biofuel and biodiesel. Another possibility of feedstock is microbial lipid produced by fermentation of soluble sugars (heterotrophic) or directly produced by algae (phototrophic). The R&D gaps for these pathways range from applied biology to improve microbe stability to construction of demonstration units large enough to obtain competitive prices. If cellulose can be used as feedstock some cost benefits are expected on the long run.

The biochemical conversion route actually includes diverse feedstocks such as municipal solid waste, flue gas rich in carbon monoxide and fermentable sugars, either from plants, starch conversion or hydrolysis of cellulosic material. Most of the pathways produce alcohols as intermediate products that are transformed into jet biofuel through the ATJ process, which is going through the approval process as an annex by ASTM. The other possible route, which has beem treated in this report as DSHC (Direct Sugar to Hydrocarbon), was approved by ASTM in June/2014 as Annex 3 – Synthesized Iso-Paraffins (SIP) for blending of up to 10% with conventional jet fuel. The route uses genetically modifies microbes to convert the sugar, followed by a soft hydrogenation to obtain the jet biofuel. Another possible fermentation route, which was not represented due to process complexity and high cost, is through biomethanation of residues, followed by GTL (gas to liquid) processes to obtain liquid biofuels.

There are several R&D gaps to be filled according to the development stage of each particular pathway, as for example: to develop more selective catalysts to convert alcohols more efficiently to jet biofuel; to improve the conversion efficiency of sugars to hydrocarbon; to develop microbes more resistant to contamination by synthesis gas produced through gasification; to advance municipal waste separation and to improve fermentation of the organic fraction; to reduce the cost of enzymatic hydrolysis to produce fermentable sugars or ethanol; to overcome the phase of demonstration units and reach commercial ones for all the pathways.

The main commercial gap for the pathways that go through sugars or ethanol, is that the market price of these intermediate products is high due to possible uses as food or road biofuel. Due to the large Brazilian experience in producing sugar and ethanol from sugarcane and the existence of a well-established agro-industrial sector dedicated to the field, the natural reference price for liquid biofuels probably will be ethanol. In energy terms, the actual ethanol consumption in Brazil as road biofuel is more than one and a half times all aviation fuel consumption (ANP, 2012). Once again, it is necessary to establish a governmental program to treat Brazilian biofuels in an integrated way to avoid the competition for feedstock between aviation and road biofuels.

The main feedstock for the thermochemical route is lignocelluloses that is available in sufficient amounts to substitute all conventional liquid fuels in the country. An ASTM approved pathway using this route to get to jet biofuel using the Fischer-Tropsch process already exists. The origin of the lignocellulosic material can be sugarcane bagasse, wood, forestry residues or any other biomass.

Although the cost of the raw material in the field can be very low, the transportation cost is important and limits the size of the processing plant, with large implications on investment cost. Other possible route using lignocellulosic biomass is to start with pyrolysis, obtaining bio-oil and biochar, intermediate products that could be transported economically through longer distances, to be then submitted to gasification and synthesis by the Fischer-Tropsch process. The cost of the process is still considered high due to the very special conditions required by the reactions (high temperature and pressure), demanding large reactors to decrease cost. Worth mentioning that the F-T process produces not only jet biofuel but also renewable diesel and gasoline, which should be considered together in a biofuel integrated program.

The main development gap in this pathway is the gasification and gas cleaning processes that are not designed for the available Brazilian biomass.

A promising pathway alternative to Fischer-Tropsch, which has being researched mainly outside the country, is to obtain a bio-oil through fast pyrolysis or solvent liquefaction, which could be upgraded in an existing refinery infrastructure, reducing costs of up-grading.

The transformation of the bio-oil in jet biofuel is done by deoxygenation processes. The main R&D gap in this case is that hydrodeoxygenation of bio-oils needs extreme conditions of temperature and pressure, with specific catalysts and expensive hydrogen.

Table 37 presents a list of pros/cons of the selected crops/feedstocks and the refining technology discussed.

Table 36 Pros and cons of selected crops/feedstocks and refining technologies.

FEED-STOCK GROUP	SELECTED CROPS/ FEED-STOCKS	REFINING TECH-NOLOGY	PROS	CONS	CO-PRODUCT	REMARKS
Oil	**Palm**	**HEFA**	- Present high productivity ~5,000 liters of oil/ha.year. - High productivity and is considered an "energy crop".	- There is potential in Brazil, however planted area is still small (Brazil still imports palm oil, mainly for food). - The main gap is to create conditions for the expansion of the planted area.	- Palm kernel oil has potential. - Palm plant also produces high quantities of lignocellulosic material. - Food security and deforestation will probably not be a barrier for palm oil as long as plantations are developed in low yield pasture lands.	- Deforestation may be an issue because palm requires much water and is best grown in rain forest regions (closer to the Amazon) - Needs long term R&D.
	Soybean	**HEFA**	- Traditional crop, produced in large areas in Brazil (27 Mha). - Brazil is presently the world largest exporter of soybean. - Consolidated scientific research in Brazil.	- Low oil content, low energy yields and reduced perspective for research focused on increasing oil content, given that the protein market is still more relevant for soybean producers and crushers. - Monoculture	- Soybean meal (cake) is used as animal feed	- Although oil and meal do not compete, because they are co-products, soybean is strongly connected to the food markets.
	Camelina	**HEFA**	- Can be planted in intercrops in the Brazilian "cerrado", therefore requiring "no extra" land.	- Oil yield of this crop is still not known in Brazil, although potentially higher than that of soybean, is lower than palm. - Requires N fertilization.	- Camelina meal (cake) is rich in Omega 3, therefore with high commercial value.	- Barriers can be overcome if camelina turns out to be an efficient second crop, which still needs to be proved for Brazilian conditions. - Needs long term R&D.

Table 36 Pros and cons of selected crops/feedstocks and refining technologies (continued).

FEED-STOCK GROUP	SELECTED CROPS/ FEED-STOCKS	REFINING TECH-NOLOGY	PROS	CONS	CO-PRODUCT	REMARKS
	Jatropha	**HEFA**	- Does not compete with food.	- Commercial production is limited because several agronomic improvements still need to be solved through research. - The toxification problem of the jatropha cake has to be overcome.	- Detoxified meal as feed.	- Needs long term R&D.
Sugar/ Starch	**Sugarcane sucrose ATJF**	**Amyris Solazyme**	- Traditional crop, produced in large areas in Brazil (9 Mha). - High productivity. It is considered an "energy crop". - Brazil is presently the largest exporter of sugar and largest producer of ethanol from cane. - Consolidated scientific research in Brazil.	- Sugarcane is facing a short term gap due to supply shortage and lower yields. Sugarcane is not performing yield increases as found in the past, which requires larger investments to promote the expansion of the production. -Increasing yields is the main gap, also because production costs have increased in the last years. - Monoculture. - Sugarcane expansion is taking place towards regions with longer water deficit periods, low fertility and non-traditional areas, increasing risks and costs.	- Sugar has very good commercial value (~30% higher than ethanol)and the use of low quality sucrose helps to produce a low cost ethanol	

	Sweet sorghum sucrose	**Amyris Solazyme ATJF**	- Once integrated to sugarcane, the main gaps are related to genetic breeding oriented to increasing yields and to extending the harvesting period.	- Non traditional crop in Brazil. - The main gap is to create conditions for the integration of the crop in the sugarcane production chain. The economic rationality of sweet sorghum arises if the crop is integrated to sugarcane. - To develop an industrial process to allow the use of the starch contained in the grain is a gap in the industrialization, specially having in mind that the sorghum is to be processed in sugar mills.	- Grains and lignocellulosic materials.	- Needs long term R&D.
	Cassava	**Amyris Solazyme ATJF**	- Traditional crop in Brazil. Brazil is the largest producer.	- The main gap for cassava is that Brazil has no tradition in producing energy from starch. - Although being a rustic plant and cropped in different regions, examples in Brazil show that the achievement of high yields requires good crop management. - Mechanization is a barrier for allowing the use of cassava as a feedstock for biofuels.	- Food products.	- Needs long term R&D.

Table 36 Pros and cons of selected crops/feedstocks and refining technologies (continued).

FEED-STOCK GROUP	SELECTED CROPS/ FEED-STOCKS	REFINING TECH-NOLOGY	PROS	CONS	CO-PRODUCT	REMARKS
Lignocellulosic	**Eucalyptus**	**Gasification Fischer Tropsch** **Hydrolysis**	- Traditional crop in Brazil. Brazil presents the highest yields in the world. - High productivity. It is considered an "energy crop". - Does not compete with food. - Consolidated scientific research in Brazil.	- Similar to sugarcane, expansion is occurring in degraded areas and in areas susceptible to high degrees of water and thermal stress. Given that is very difficult to balance in a same genotype biotic resistance, tolerance to drought or frost, good productivity and good quality of wood, it is necessary to produce interspecific hybrids. - Creating the facilities and the infra-structure necessary to allow the use of residues for producing biofuels is also a gap.	- Electricity generation - Charcoal or thermal energy production - Pulp for cellulose - Pellets - Oil extractions - Wood for saw mills.	- Not available in industrial plants in Brazil.
	Grasses (elephant grass)	**Gasification Fischer Tropsch** **Hydrolysis**	- High productivity. It is considered an "energy crop". - Does not compete with food.	- The use of grasses to produce energy is something new in Brazil. Grasses have been used for animal feed; management practices such as the use of fertilizers, are still not common. - Cut, collect and dry (wet climate) large amounts of biomass is a barrier.	- Electricity generation - Charcoal or thermal energy production - Pellets.	- Needs long term R&D.

Lignocellulosic	**Grasses (elephant grass)**	**Gasification Fischer Tropsch Hydrolysis**		Costs are not known and solutions and machinery are not in the market. - Selection of more productive and efficient genotypes is also a gap.		
	Sugarcane bagasse and trash	**Gasification Fischer Tropsch Hydrolysis**	- Does not compete with food.	- A barrier for the use of sugarcane in the jet biofuel market is the high opportunity cost of the cane (sugar and ethanol markets) and the bagasse, given that it is largely used for electricity generation. Although being a residue of the cane crushing, the bagasse is not a tip free residue.	Pellets	
Wastes/ Residues	**CO_2 - algae**	**HEFA**	- Does not compete with food.	- Costly alternative. - Availability.		- Needs long term R&D.
	Steel Mill Flue Gases: CO, H_2	**Anaerobic fermentation and ATJ**	- Does not compete with food. - Low cost feedstock. - Does not require large scale. - Point sourced - Global Availability	- High CAPEX alternative - Logistic and separation issues are key barriers. Uniformity of organic fraction needed - Biogenic MSW collection costs must be competitive with current costs, unless turned mandatory by law. - Environmental legislation can potentially be a constraint because the use of solid waste should require different permits.	- Cleaner emissions	- Needs demonstration at commercial scale

Table 36 Pros and cons of selected crops/feedstocks and refining technologies (continued).

FEED-STOCK GROUP	SELECTED CROPS/ FEED-STOCKS	REFINING TECH-NOLOGY	PROS	CONS	CO-PRODUCT	REMARKS
Wastes/ Residues	**MSW**	**Fermentation** **Gasification** **Fisher Tropsch**	- Does not compete with food. - May have a "negative cost" if the proper residues policy is implemented.	- High CAPEX alternative - Logistic and separation issues are key barriers. Uniformity of organic fraction needed	- Cleaner environment.	- Needs long term R&D.
		Anaerobic fermentation of organic fraction and ATJ		- Biogenic MSW collection costs must be competitive with current costs, unless turned mandatory by law. - Environmental legislation can potentially be a constraint because the use of solid waste should require different permits.		
	Tallow	**HEFA**	- Use of residue. - Does not compete with food. - Adds value in a food chain.	- Limited quantity since it is a by-product of beef production. - Presently used for biodiesel production.	- Cleaner environment.	- Not likely to be produced in much bigger quantities due to high collecting costs.
	Used cooking oil	**HEFA**	- Use of residue. - Reduces disposal costs. - Does not compete with food. - Collecting difficulties and high costs.	- Already used in small quantities for biodiesel production.	- Cleaner environment.	- Not likely to be produced in much bigger quantities due to high collecting costs.

RECOMMENDED POLICIES

12 INSTITUTIONAL ISSUES ON AVIATION BIOFUELS

Similar to other innovative technologies, the development of aviation biofuels depends strongly on support mechanisms and proper public policies. As an immediate example, the adoption of ethanol and biodiesel in many countries required specific and active policies, in order to reduce uncertainties and risk perception among producers and promote investments, as well to protect consumers and environment.

The basic reasons behind these measures are the differential advantages and externalities of using a renewable energy, in comparison with the conventional fossil fuels. In fact, when produced and used sustainably, a biofuel is able to foster environmental benefits, jobs generation, economic activation and energy security, as main positive impacts. It is important to stress that these potential advantages of biofuels are intrinsically dependent on the production route adopted, including the feedstock productive system and the agro-industrial conversion process, which should be properly assessed by sustainability indicators. In fact, every production route should be carefully evaluated in order to determine its relative sustainability and allow justifying or not its promotion and support. In this direction several certification schemes have been put forward, involving themes such as land and water use, impact in food availability and biodiversity, among other aspects. This subject is clearly relevant and is the central theme of a workshop in the *Sustainable Aviation Biofuels for Brazil Project*.

Two basic governmental measures to support the development of sustainable biofuels are the promotion of R&D activities and the definition of a fuel specification. Regarding the first one, in the agriculture, forestry, processing and refining contexts, there are many gaps to fill, open questions to explore and processes to improve. Some feedstock proposed for aviation biofuel production, such as jatropha and algae are relatively unstudied, requiring more assessment. Several refining processes are still in bench or even in conceptual level. Venture capital can play a complementary role in R&D, but which may be especially relevant in the cases where a relatively small public research infrastructure is available and there is private interest and funds for R&D. However, clearly it is a government responsibility to organize the scientific and technological development, stimulating basic studies, promoting demonstration projects and, as an essential matter, preparing and motivating researchers. Just with proper resources, in a broad sense, is possible to screen the large number of options for aviation biofuels production systems and choose wisely the most promising ones. That R&D effort should be permanent; in order to optimize the biofuel chain. In the next topic of this chapter a preliminary agenda for R&D aiming to develop sustainable aviation biofuels is presented.

After recognizing that there are a group of few production routes that effectively deserve support, the government action towards to assist and promote biofuels development can be done essentially in two complementary ways. The first group of measures is developed in the regulatory sphere, where a clear biofuel specification must be defined and, if convenient, a mandatory blending program can be implemented, possibly following an initial demonstration and voluntary programs. The second group comprises the economic incentives that can be adopted to promote the production and use of a biofuel.

a. Biofuel selection specification

The biofuel selection must attend simultaneously the environment, engine and producer's requirements, which are in conflict in many cases, and impose a judicious analysis before the final decision. In the case of aviation biofuel, as observed, the globalization of demand and stringent conditions of use and safety standards imposes the "drop-in" concept. A widely accepted procedure for biofuel approval process is already available (ASTM D4054, *Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives*); feedstock plus conversion process, according to a specific standard (ASTM D7566, *Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbon*) and its annexes. In 2014 was approved by ASTM the use of SIP (Synthesized Iso-Paraffins produced from Hydroprocessed Fermented Sugars) as aviation fuel in blends up to 50%.

The ASTM standards for fuels have been endorsed by ANP, the regulatory agency with legal mandate for setting fuel specifications in Brazil. In the case of jet fuel, ANP Order 37/2009 (Jet Fuel Specification) endorses the D7566 (Specification for Aviation Turbine Fuels). In 2012 ANP initiated the discussion to amend this order allowing the use of aviation biofuels accordingly the ASTM Standards. As a recent relevant action in this context and a decisive step towards the introduction of biofuels in the commercial aviation, in June 2013 the ANP launched the Brazilian Specification and rules for distribution and use of Aviation Biofuels (Resolução ANP Nr. 20/2013), issued after a regular process of consults and discussion with stakeholders of aviation industry, biofuel producers and governmental agencies. In the preamble of this order, it is mentioned the Law Nr. 12.490/2011, which sets aviation biokerosene as a "substance derived from renewable biomass that can be used in turbojets and turboprops aircraft or, as regulated in another type of application that can replace partially or totally the fuel of fossil origin". Thus, the quality aspect of aviation biofuel is enough well defined and put forward. Some improvements are needed in the regulations to make explicit the role of jet biofuel producers in the country, anticipating and promoting the expected aviation biofuel industry.

b. Mandatory blending

Creating an assured demand, a mandatory blending of a biofuel in a conventional fuel is certainly a powerful measure to promote its adoption and production. This approach was used to introduce biofuels in Brazilian market, applied to ethanol in 1931 and to biodiesel in 2003. However, the particular conditions of aviation demand, with an international and domestic fleet dividing the same infrastructure and the fuel consumption distributed over all national territory, create difficulties that should be previously considered, deeply discussed and solved before any action towards the compulsory use of biofuels.

Learning from the lessons of succeeded experiences of implementing biofuel introduction as vehicular fuel in some countries, its worth to plan carefully before any action and consider a phased and progressive introduction, initiated with a period of voluntary blends. Unexpected and diversified problems in biofuel production and distribution can occur, requiring adjusts, improving and orientating the next steps. Another crucial aspect to take into account is the respect to the stakeholder's perception, which requires promoting a permanent and fluid exchange of information and dialog with all agents interested in the process. Even when adopting a mandatory blending, determined by legal procedures, the introduction of a biofuel should be the result of convergence, not force.

Besides those considerations, and because jet biofuels probably will use the same or similar feedstocks as the biofuels already utilized for road transportation in Brazil, it is fundamental to establish a program for integrated use of biofuels in all transportation modes in the country.

c. Incentives and financing

As initially stated, the government commitment, expressed not only in proper regulation, but also in economic incentives and related supporting mechanisms, is essential to biofuel development in sound bases. Different economic supporting schemes have been implemented in order to make feasible and attractive the biofuel production and use, which can be classified as:

1. basic and applied research direct funding, covering scholarships, equipment and operational costs financing, support for technical missions and events, and other similar;
2. financing of bench studies and scale-up of production units, up to demonstration plants level;
3. financing of implementation of economic scale production plants, involving feedstock supply systems, processing units, logistics, etc;
4. financing or other economic mechanism to promote biofuel use, reducing the initial cost associated to its introduction, as quality control systems, storage tanks, etc;
5. differential and balanced tax regime, specific to capital expenditures and other items related to biofuel production.

Of course that, in this situation, risks and uncertainties increase with the investment level, imposing careful analysis to avoid undesirable losses and financial difficulties. Good and detailed planning are crucial elements in this context.

Finally, it is important to mention that, in any country, the development of a sustainable aviation biofuels market only can be done based on a clear national strategy towards its introduction, recognizing its relevance for the society and the environment. This strategy should be implemented by an action plan, joining and coordinating the government bodies and stakeholders, with well-defined targets and advance indicators. As an excellent example of integrated and coordinated effort towards to develop aviation biofuels, the US program is briefly commented in **Box 4**.

Box 4: The American Aviation Biofuels Program: an example to Brazil?

Aviation biofuels are explicitly present in the agenda of several American institutions, mainly at Federal level, and a well-organized set of programs and activities was put forward and currently are in development in several fronts. Even considering the possibility that Federal budget constraints may impact negatively this objective, the studies and assessments already done have established relevant references and basic objectives were defined, with the involvement of public and private stakeholders, motivating potential producers and users. The guiding questions are related to resource assessment, techno-economic analysis and sustainability evaluation.

The fundamental drives to introduce aviation biofuels in the United States market are:

1. to develop a renewable sustainable alternative to a fossil fuel strategically relevant, largely imported, presenting worrying price volatility and the most important component of operational cost for airlines, and,
2. the global concern with GHG emissions, as recognized by international organisms such as ICAO and IATA, and reason for additional taxes for airlines, in the framework of carbon emission taxation such as the European Tax S, in discussion for implementation.

The interest in energy security is clear in this context, at least from the perspective of Navy, as can be noted in its call for proposals (Advanced Drop-In Biofuels Production Project, Navy Funding Opportunity Announcement 12-15-PKM), which presents as the first requirement for such biofuel to “be produced domestically”. The environmental concerns are always mentioned and associated to the compliance with the Energy Independence and Security Act (EISA) Section 526, which states that biofuels should observe the Renewable Fuel Standard, issued by the Environment Protection Agency in 2011, restricting the use of biofuels on the basis of their life-cycle GHG emissions.

A convincing signal of the American governmental involvement and compromise towards aviation biofuels is the Defense Production Act Funding. By this instrument, the Department of Agriculture, Department of Navy, and the Department of Energy have committed to fund $510 million to assist the development and commercialization of a sustainable industry for aviation and marine biofuels, and to foster mutual cooperation among the federal agencies and across the public and private sectors.

From the American experience it was possible to learn that it is highly desirable to have good institutional coordination, with clear responsibilities for the agencies and personnel involved (USDA: feedstock production; DOE: technologies development, FAA: conditions for using, etc.). It is decisive as well to have a foreseeable program for future acquisition and blending, in order to reduce risk perception and create effective pushers for potential aviation biofuel producers.

13 R&D PROGRAMS AND COMMERCIALIZATION GAPS

In broader terms R&D programs need to be created having defined its objectives considering the biofuels for aviation goals and the large number of pathways to be considered. Therefore the R&D program for biofuels for aviation can have the following objectives to overcome existing gaps:

1. make the pathway technically feasible, when there is a need to demonstrate technical-commercial feasibility;
2. reduce CO_2 emissions (LCA), when the biofuel net CO_2 emissions is still too high to justify its use;
3. reduce biofuels production costs, when the biofuel final production price (cost + profit margin) is still above the jet fuel market price;
4. improve the environment and socio-economic indicators, when its benefits are still not significant.

Commercially, it is important to recognize that successful biofuels have built their economic viability on co-products. This was the case of Brazilian sugarcane ethanol with sugar, the American corn ethanol with corn cake used as feed, and of soybean biodiesel in different countries, where soybean cake was commercialized as feed. Of course the co-product market size and characteristics will also determine how the biofuel-co-product economic equation will be built. However, it is recognized that when aviation biofuel is been considered, an important strategy to obtain a lower cost biofuel certainly is by obtaining value added-products.

Besides the above drivers for R&D definition, it is also essential to define an R&D strategy (approach) to be followed. This will determine the efforts, translated as the amount of financial and human resources to be invested, and future accomplishments and benefits.

1. **Research approach type 1** should guarantee incremental gains in productivity or efficiency objecting to reduce cost and mitigate CO_2 emissions. This type of research approach will guarantee a medium-long term learning curve, similar to what was experimented by the Brazilian sugarcane ethanol Program. Examples of this type of research are: the development of new plant varieties and the introduction of better management practices such as to improve cane logistics.
2. **Research approach type 2** aims at generating breakthroughs changing the existing paradigm and at causing great effect in the overall production efficiency with significant reduction on costs, CO_2 emissions and also land use. Examples: i) the improvement of plant photosynthesis (even for C4 plants the photosynthetic efficiency is very low, about ~3%) can cause great impact on biofuels, affecting cost, CO_2 emissions, and mainly land use; ii) to develop genetically modified plants to produce biomass in arid lands (abundant worldwide and presently offering very low agricultural yields) can both have a significant impact on reducing hunger by increasing food production in poor areas of the globe and also allowing biofuels production in marginal lands; iii) to develop processes such

as hydrolysis or FT can allow the use of lignocellulosic materials which are much more abundant and easy to produce then sugar, starch, or oil.

3. **Research approach type 3** focus not on improving the system performance such as discussed in the previous cases, but rather, on the great surroundings of the biofuels production systems where most activities take place for the production of food and fiber today. It is recognized that presently 3.5 billion ha worldwide are devoted to pasture land (all types, including grasslands, planted pasture, etc.) and another 1.5 billion ha are presently used in agriculture. Just to exemplify, of all kerosene presently used for aviation (~250 billion liters) was to be replaced by biofuels using overall yields from 5,000 to 7,000 liters/ha/year (for palm oil in Malaysia and sugarcane ethanol in Brazil), the required amount of land would range from 35 to 50 million ha (LEAL et al., 2013). Therefore, between 1 and 1.5% of land currently used in pasture land or 2.5 to 3% of land used for agriculture.

14 CONCLUSIONS

The Sustainable Aviation Biofuels for Brazil Project proposed and implemented an enriching experience involving important stakeholders from different sectors of Brazilian society: government sector, agriculture, aviation industry, regulatory agencies, NGOs, universities and research institutions. The Project proved to be an endogenous creative output, a Brazilian contribution to a sustainable aviation industry.

The following conclusions and correspondent actions were drawn from the several activities of the Sustainable Aviation Biofuels for Brazil Project.

Why Brazil?

Past Brazilian experience on feedstock for modern and sustainable production of biofuels has shown the fundamental importance of large scale for economic competitiveness with fossil fuels. Brazil has accumulated technical experience in agriculture and industry, institutional capacity, and great popular acceptance. This makes it an excellent environment to begin the new jet biofuel industry worldwide.

After the Brazilian ethanol program was created in 1975, it did not only help this country to alleviate its fossil-fuel dependence but also helped to modernize Brazilian agriculture. Since 1975 Brazil has become a net exporter of agricultural goods, including grains, meat and other products. Brazil is one of the world´s best examples of the potential for reconciling sustainable biofuel production with food security.

The current production of bioenergy in Brazil is much larger, in energy terms, than total jet fuel consumption in the country, a fact that will compel jet biofuel to conform to feedstock prices already established in the market.

Brazil only utilizes 8% of its land for agriculture (60 million ha out of 850 million ha total), much below industrialized nations such as USA's 15%, and the 30-40%.in most European countries. The report concludes that the country has abundant available land for bioenergy through increasing productivity on existing agricultural lands, which could be an example for the world, if land use is optimized in this way.

Aviation Industry Goals

The Brazilian aviation industry, including EMBRAER, Brazilian main airlines, Petrobras Aviation and all involved regulatory agencies and related institutions, has demonstrated deep commitment to the introduction of jet biofuels in aviation in Brazil.

Air transportation is indispensable in modern life, so a stable and safe supply of jet biofuel at competitive cost is crucial for the aviation industry to grow in an environmentally sustainable manner, meeting industry goals for carbon emissions reduction.

Aviation biofuel processing will possibly have to be integrated at least with liquid biofuels for road, rail and water transportation, if it is to be competitive in economic terms with fossil fuels. Scale and chain optimization are crucial for the fuel business and the cost of drop-in jet biofuel is higher than that of road biofuels.

Although expensive, the ASTM certification procedure and the associated drop-in concept reduce barriers to introduce aviation jet biofuels and should be taken into account strictly.

Which Feedstocks to Use in Brazil?

There is no single, perfect feedstock to produce a jet biofuel in Brazil. The stakeholders agree that work should continue on a variety of feedstocks to ensure the greatest likelihood of adequate availability and getting to scale.

A diversity of feedstocks is available for different growing conditions. Eucalyptus can use land with high slopes. Sugarcane grows in the tropical and subtropical zones while different crops are suitable to different latitudes such as palm in south Pará State; starch and oil crops can be grown in most of Brazil, and these includes non-food crops such as camelina and jatropha, and other feedstocks with promising futures, if more R&D is implemented.

Brazil's past experience with biofuels also shows that crops which can supply feedstock for diverse applications, for instance food, fuel, pulp, have a larger chance of success.

Just to demonstrate how important agriculture productivity is, sugarcane bioethanol uses only 0.5% of Brazilian territory and represents around 35% of all fuels used for light vehicles in Brazil, besides bioelectricity production. Sugarcane total contribution to primary energy used in Brazil is almost half that of the petroleum. Using ethanol or sugar from sugarcane to produce jet biofuel, less than 0.3% of Brazilian territory would be enough to substitute all jet fuel currently used in Brazil.

Considering the 2020 horizon, the most productive sources of bioenergy from the standpoints of crop yield and energy balance are sugarcane and forestry. These would be the option of choice for aviation biofuels if this was the final criteria. But the problem is much more complex, and the optimization of the country´s ample land resource may contemplate other crops as well.

Therefore the following methodology is proposed to evaluate feedstock substitution:

For each promising feedstock (for diverse applications or only for biofuel), and applicable refining process, the best identified site for producing enough feedstock to substitute should be chosen, let us say, 2% of jet fuel consumption, and, for that special situation, the effects of producing feedstock for biofuel on the local agriculture and its sustainability for the next generations should be analyzed. The following issues should be fulfilled for the substitution to be valid:

a. Evaluate the present economic benefits of the specific site and compare them to the benefits that would be obtained if the new feedstock (even if only for energy) was to be grown there. Consider the prices for one or two decades ahead bearing in mind the maximum feedstock price compatible with an energy price of biofuel equal to the price of conventional fuel. Neglect eventual land valorization and food price increases resultant directly from the implementation should not be considered as benefit. The results should be favorable to feedstock for biofuel production;

b. Evaluate the social and environmental impacts in the region, including small properties and family agriculture, and compare the sustainability indicators with the ones for the present occupation. The results should be favorable to feedstock for biofuel production.

Which are the Identified Pathways?

Considering pathway as a combination between a given feedstock and a refining technology, 13 pathways were identified in the *Sustainable Aviation Biofuels for Brazil Project*.

Of course, there are many combinations of feedstock and process likely to be feasible alternatives for aviation biofuel production in the medium-long term.

Given that not a single solution could be selected, the *Sustainable Aviation Biofuels for Brazil Project* has recommended the most promising and sustainable alternatives for implementing more R&D efforts.

Promising short-term possibilities include the use of sugarcane sucrose and ethanol, since they can benefit from low sugarcane production costs and good sustainability indicators in Brazil. However, in the medium to long term, it appears that fiber cellulosic feedstocks such as wood-derived products and sugarcane trash and bagasse will have better competitive possibilities due to their high sustainability values. Several other feedstocks may have medium and longer term potential for cost effective production.

What are the Impacts? What about Sustainability Issues?

The basic reasons for the increasing global interest in aviation biofuels are: to reduce volatile fossil energy costs, to improve energy security and to mitigate GHG emissions.

The most critical jet biofuel features are the potential to mitigate GHG emissions and to be produced at competitive costs. Alternatives that supply low costs and high emissions or low emissions and high costs are not, strictly speaking, considered sustainable solutions, even though some positive externalities could justify their acceptance.

Another important finding of the *Sustainable Aviation Biofuels for Brazil Project* was the difficulty to access reliable data on Life Cycle Analysis (LCA) and production costs for the different analyzed pathways under Brazilian conditions. Further R&D is considered essential to overcome the identified gaps, see **Table 37** below.

In the Brazilian context of abundant opportunities to increase the productivity of existing agricultural lands, biofuel production can be accelerated without endangering food security, if the relevant policies are implemented, as we have validated in the Sustainability Indicators section above.

The real issue is how to improve the sustainability of agriculture in general, which requires economic resources to promote the farmer's necessary cultural change. This aspect can be somewhat improved when agriculture is upgraded by economic resources transferred from urban areas, for instance to pay for feedstock for biofuels.

As presented in the sustainability workshop, the social and environmental issues should not be treated statically. Similarly to the necessary learning curve for the production cost, environmental and social performance should be improved over the long run to build-up a sustainable biofuel industry.

Because aviation is largely an international business, it is very important to utilize sustainability criteria that are agreed upon internationally, such as those of the Roundtable on Sustainable Biomaterials and Bonsucro.

To fill social and environmental gaps Brazilian institutions must identify practical ways to use the opportunity of growing energy feedstocks to push sustainability culture into the whole of Brazilian agriculture. Also, it is recognized that research initiatives are fundamental to improve performance to sustainability indicators by developing appropriate technologies, both to lower feedstock production costs and reduce unwanted impacts.

Which R&D Efforts are Necessary?

R&D is an essential element to render a possible and sustainable given pathway. Brazil has dedicated substantial R&D efforts that allowed sugarcane and eucalyptus to be competitive crops for biofuels. Therefore much more is needed for other crops and pathways.

Among the production pathways, the Hydro-processed Esters and Fatty Acids (HEFA) and Synthetic Paraffinic Kerosene by Fischer-Tropsch (SPK FT) processes are already in place. Alternatives based on sugar/lignocellulosic feedstock, as Alcohols to Jet Fuel (ATJ) and some advanced biobased processes (Synthetic Kerosene from Metabolic Process), all still in pilot phase, also present good potential. A properly designed R&D program in aviation biofuel is necessary to screen the several pathways for feedstock and processes, which should be evaluated mainly for prospective economic competitiveness, LCA and other environmental and social impacts.

Technological gaps and actions – improve agricultural productivity of identified feedstocks and research to find new ones; improve energy efficiency of processing technologies and develop new processes; study the best location and incentivize the construction of demonstration and first commercial plants for the main identified routes for jet biofuel production; extend the installed competence for testing and certification of jet biofuel throughout the country.

Which Infrastructure Actions are needed in Brazil to Allow an Adequate Logistics of Feedstocks and Biofuels?

Brazil has important bottlenecks in logistics and needs, both for feedstock and biofuel transportation, to overcome the barriers and help making a competitive biofuel. Although they require attention, blending logistics and specs regulation issues seem to be properly outlined by ANP´s Resolution Nr. 20/2013 and, due to the “drop-in” concept, do not represent insurmountable obstacles to aviation biofuels. However, explicit investments will be necessary in storage and blending facilities.

Jet fuel consumption is specially concentrated in the country’s southeast, but in general in cities not far from the seashore. On the other hand, there is abundant agricultural inexpensive land available in the interior of the country, far from the consumption centers (distances larger than 1000-2000 km). Therefore, improvement of feedstock and jet biofuel logistics is a significant need for economic competitiveness of the various pathways for production of jet biofuel. On the other hand, the diversity of available feedstock and specific consumption sites in different regions of the country can impel the materialization of niche solutions taking advantage of long distance and high logistics cost, depending on installed competence for testing and certification of aviation fuels.

Economical gaps and actions – develop logistic studies for investment on railways and waterways taking into account feedstocks for biofuels in general and jet fuel specifically; make sure that the cost advantage of Brazilian agriculture products in international markets be reflected in aviation biofuels production. similarly to other biofuels; take actions to ensure that the cost difference of aviation biofuel to conventional fuel in Brazil be smaller than in other countries, in a way that the possible exportation of jet biofuel through international flights can lift the competitiveness of the aviation biofuels industry established in the country.

Is Brazil ready to build the new biofuels for aviation industry?

After decades of regular use of ethanol and mandatory biodiesel blends since 2005, with the active participation of government, Brazil offers a real experience on how to introduce a biofuel in the market. However, despite the previous experiences with production and use of biofuels in Brazil, there are important and relevant institutional issues when the construction of the new biofuels for aviation industry is considered.

Under this scenario, the Sustainable Aviation Biofuels for Brazil Project has identified the main institutional issues relevant to aviation biofuels development in the Brazilian context:

a. the development of the aviation biofuel production in Brazil, associated or not with the current biofuel industry, is able to open a new and innovative chain of sustainable bioenergy, with a growing global demand. Thus, it should be considered strategic and evaluated not only from the immediate point of view, but taking into account its potential to foster economic, environmental and social benefits;

b. institutional conditions are decisive for promoting aviation biofuels, especially with regards to incentives and financing mechanisms, imposing well designed and coordinated public policies. Government actions in this direction are observed in Brazil, but more is needed, especially in terms of energy policy, to define the role expected for this renewable fuel in the future and for this new industry;

c. aligned with the principles of “drop-in” and adopting a worldwide specification, implemented with regular balloting with stakeholders, ANP is providing solid backing to aviation biofuel development and implementation in Brazil, in cooperation with the civil aviation agencies, ANAC and SAC;

d. it seems relatively premature to recommend targets for mandatory blending of aviation biofuels in Brazil, but studies in this direction are advisable and should be done in order to assess the alternatives, evaluating their implications, costs and benefits;

e. there are several financing mechanisms that can be directed to promoting aviation biofuels R&D activities and demonstration projects;

f. biofuels production and use involve necessarily several ministries and interests (Agriculture, Energy, Environment, Science and Technology, Defense, etc.) and aviation biofuels of course include another group of agencies and issues. Thus, all stakeholders and decision makers should be included in the discussion and evaluation of alternatives and aims. Since R&D are the prevalent activities at this point, it is recommended that, at least in the pathways screening stage, the leading role must be kept by science and technology agencies at federal and state levels, in an active collaboration with all stakeholders to set practical parameters and identify needs that drive R&D towards effective implementation.

What are the Main Policies and Actions Required to Implement the New Jet Biofuels Industry in Brazil?

Public policies are essential to develop agro-industrial technology for aviation biofuels, as well as to implement financial and regulatory measures able to support aviation biofuels production and use. In this context, how to share the costs and benefits of aviation biofuel adoption should be analyzed and discussed.

Presenting simultaneously favorable conditions to foster biofuels production, a large experience with automotive biofuels and an active aviation industry, Brazil is exceptionally well posed to put forward a program of aviation biofuels, with clear targets, clear supporting mechanisms and participation of all stakeholders. It is important to recommend policies to support the deployment of new technologies pathways from, for example, start-up companies. Nowadays, Brazil lacks such policies in this area.

Long-term biofuels policies, which integrate fuels for all motorized transportation modes and recognize the particular need of aviation for sustainable fuel alternatives, will have to be established to make aviation biofuel economically viable due to the extra cost of producing a “drop-in” fuel.

Institutional gaps and actions

a. improve the Brazilian set of regulations relative to aviation fuels to explicitly recognize the role of biofuel producers in the country;

b. establish the “drop-in” sites as far as possible downstream in the distribution chain without compromising fuel quality and certification requirements of aviation sector;

c. observe closely and anticipate regulatory actions by ICAO in such a way to take advantage of international regulations to promote a jet biofuel industry in Brazil;

d. establish a governmental long-term program for integrated use of biofuels in all transportation modes in the country, to neutralize the cost difference of producing a “drop-in” fuel versus a product for biofuel-adapted engines as is the case for road transportation.

Table 37 presents a tentative list of limiting factors and policy recommendations for Aviation Biofuels development, to answer those questions taking into account the particular Brazilian context. This table is a preliminary summary, since a deeper reflection and discussion on these perspectives, involving stakeholders, will address these needs in a more complete way. However, other relevant and more specific recommendations have been addressed and detailed in all *Sustainable Aviation Biofuels for Brazil Project* workshops.

In conclusion, the substitution of fossil fuels for aviation represents a very import niche for sustainable biofuels and Brazil has a great opportunity in this area to become a global player. There are important challenges to be overcome to create the basis for this new emerging industry and Brazil cannot afford not to participate.

Table 37 Limiting factors and policy recommendations for Aviation Biofuels development.

Issue	LIMITING FACTORS			POLICY RECOMMENDATIONS		
	CURRENT	FUTURE	RELEVANCE/ PRIORITY	IMMEDIATE/SHORT TERM	MEDIUM TERM (2020)	LONG TERM (2050)
Feedstock	• Limited information about species with potential for bioenergy • Limited information on land zoning for bioenergy • High costs for producers to comply with environmental and social regulations	• Risk of constraints in natural resources supply (water, chemicals, etc.) for efficient biomass production • Risks of expanding biofuels production with high impacts on land use change	Medium/ High	• Promote the development of human resources • Promote LCA studies on crops with bioenergy potential • Evaluate gaps and mechanisms to allow producers to become regularized	• Promote advanced agronomic studies on bioenergy crops • Develop assessment on residues availability and collection • Promote above trend yields increase	• Promote studies on innovative sources of biomass for bioenergy
Refining	• Lack of information about process feasibility, high technology risk.	• Technology risk associated to development of innovative process	High	• Promote the development of human resources; • Support (financing) for pilot and demonstration	• Support (financing/ regulatory) aviation biofuel demonstration programs and commercial use.	
Logistics	• Infrastructure constraints		High	• Evaluate needs of regions with potential for biofuel production.	• Promote logistics improvements; • Assess new productive schemes, reducing transport of bulky biomass.	
Sustain-ability	• Need for successful enforcement of social and environment laws.	• Protect workers, and avoid potential loss of Brazil´s major natural resources.	High	• Establish legal mechanisms to ensure that incentives for aviation biofuels are only available where national laws and regulations, especially natural forest and other habitat protections, land use zoning and worker protections, are demonstrated to be fully implemented.		

Table 37 Limiting factors and policy recommendations for Aviation Biofuels development (continued).

Issue	LIMITING FACTORS			POLICY RECOMMENDATIONS		
	CURRENT	FUTURE	RELEVANCE/ PRIORITY	IMMEDIATE/SHORT TERM	MEDIUM TERM (2020)	LONG TERM (2050)
Sustainability	• Need for monitoring of performance of aviation biofuels to international social and environment standards.	• Prevent difficulties to Brazil's aviation biofuels production and trade.	High	• Consolidate the sustainability certification process.		
				• Research and incentives only for feedstocks systems which increase overall productivity of energy and food/feed/fiber on same land.		
General	• Lack of co-ordination among governmental agencies and stakeholder in fostering aviation biofuels; • Lack of information about aviation biofuels among decision makers and public.	• Heterogeneity and lack of clarity in the sustainability evaluation of biofuels.	High	• Launch an aviation biofuel program, with a clear agenda of strategic actions; • Promote information campaign on potential, benefits and implications	• Assess and issue regularly indicators of the aviation biofuels program; • Consolidate the sustainability certification process.	

REFERENCE

ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15216:** armazenamento de líquidos inflamáveis e combustíveis: controle da qualidade no armazenamento, transporte e abastecimento de combustíveis de aviação. São Paulo, 2010.

ABRABA – ALIANÇA BRASILEIRA PARA BIOCOMBUSTÍVEIS DE AVIAÇÃO. Available at: <http://www.abraba.com.br>. Access on: September 2nd 2012.

ABRAF – ASSOCIAÇÃO BRASILEIRA DE PRODUTORES DE FLORESTAS PLANTADAS. **Statistical yearbook 2012**: base year 2011. Brasília, DF, 2012. 150p.

ADAMI, M. et al. Remote sensing time series to evaluate direct land use change of recent expanded sugarcane crop in Brazil. **Sustainability**, Basel, v. 4, n. 4, p. 574-585, 2012.

AGRIANUAL. **Agrianual 2012:** anuário da agricultura brasileira. São Paulo: FNP, 2012. 512p.

ALVES, R. G. M. L. **System to transform waste into synthetic hydrocarbon comprises waste and biomass gasification, and Fischer-Tropsch hydrocarbon synthesis subsystems; and electricity and heat co-generation, and hydrogen generation and injection subsystems**. US 2011158858-A1, April 18 2007, June 30 2011.

AMYRIS. **Sustainable aviation biofuels for Brazil project**. Campinas: SABB, 2012.

ANFAVEA – ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE VEÍCULOS AUTOMOTORES. **Brazilian automotive industry yearbook, 2013**. São Paulo, 2013. 164p.

ANP – AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. **Anuário Estatístico do Petróleo e Gás Natural e Biocombustíveis**. Brasília, DF, 2007. 190p.

ANP – AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. **Anuário Estatístico do Petróleo, Gás Natural e Biocombustíveis**. Brasília, DF, 2012. 250p.

ASTM – ASTM INTERNATIONAL. **ASTM D4054-09:** standard practice for qualification and approval of new aviation turbine fuels and fuel additives. West Conshohocken, 2009.

ASTM – ASTM INTERNATIONAL. **ASTM D7566-11a:** standard specification for aviation turbine fuel containing synthesized hydrocarbons. West Conshohocken, 2011.

ASTM – ASTM INTERNATIONAL. **ASTM D1655-12:** standard specification for aviation turbine fuels. West Conshohocken, 2012.

ATAG – AIR TRANSPORT ACTION GROUP. **Beginner's guide to aviation biofuels**. Geneva, 2011. 24p. Available at: <http://www.atag.org/component/downloads/downloads/97.html>. Access on: January 28th 2013.

AXELSSON, L. et al. **Performance of jatropha biodiesel production and its environmental and socio-economic impacts:** a case study in southern India. Linköping: World Renewable Energy Congress, 2011. 8p.

BARTHOLIC, D. B. **Improved fluidized catalytic cracking method for residual oil with high conversion**. JP 2000336375-A, May 2 2000, December 5 2000.

BELTRÃO, S. **Biodiesel**: history and perspectives. Campinas: SABB, 2012.

BERENCHTEIN, B. et al. Use of biodiesel co-product from Jatopha curcas as ingredient for animal feed. **Advances in Animal Biosciences,** Cambridge, v. 1, n. 1, p. 286, 2010. Available at: <http://journals.cambridge.org/action/displayFulltext?type=1&fid=7927845&jid=ABS&volumeId=1&issueId=01&aid=7927844>. Access on: September 3 2014.

BIGNAZZI, R. et al. **Process for the production of algal biomass with a high lipid content**. IT 20110020913, December 3 2008, January 27 2011.

BLAKEY, S. et al. **State of the art on alternative fuels in aviation**: SWAFEA: Sustainable Way for Alternative Fuels and Energy in Aviation. Paris: Onera, 2010. 19p. Available at: <http://www.eurosfaire.prd.fr/7pc/documents/1295880328_swafea_resume_etude.pdf>. Access on: September 3 2014.

BLANCH, H. W. Bioprocessing for biofuels. **Current Opinion in Biotechnology**, London, v. 23, n. 3, p. 390-395, 2012.

BON, E. S.; FERRARA, M. A. Bioethanol production via enzymatic hydrolysis of cellulosic biomass. In: THE ROLE OF AGRICULTURAL BIOTECHNOLOGIES FOR PRODUCTION OF BIOENERGY IN DEVELOPING COUNTRIES, 2007, Rome. **Proceedings...** Rome: FAO, 2007. Available at: http://www.fao.org/biotech/docs/bon.pdf. Access on: January 28th 2013.

BRACELPA – ASSOCIAÇÃO BRASILEIRA DE CELLULOSE E PAPEL. **Relatório Florestal 2009**. Brasília, DF, 2009. 16p. Available at: <http://www.bracelpa.org.br/bra/estatisticas/pdf/anual/RA_02.pdf>. Access on: January 28 2013.

BRASIL. Ministério de Minas e Energia. **Programa Nacional de Produção e Uso de Biodisel, PNPB.** Brasília, DF, 2004. Available at: <http://www.mme.gov.br/programas/biodiesel/galerias/arquivos/biodiesel/cartilha_biodiesel_portugues.pdf >. Access on: January 28 2013.

BRASIL. Ministério de Minas e Energia. Conselho Nacional de Política Energética. **Plano Nacional de Energia 2030**. Brasília, 2007. Available at: <http://www.epe.gov.br/PNE/20070626_1.pdf>. Access on: September 4 2014.

CAAFI - COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE. Available at: <http://www.caafi.org>. Access on: January 20 2012.

CANTARELLA, H. **Visit Report of SAAB Committee to the Camelina Company Spain**. SAAB Report, February, 11th and 12th, 13p., 2013a.

CANTARELLA, H. **Visit Report of SAAB Committee to Ribas do Rio Pardo, MS. Jatropha (Jatropha curcas) experimental and production area of Rio Pardo Bioenergia Ltda & SGB**. SAAB Report, January, 9th to 11th, 16p., 2013b.

CANTARELLA, H. et al. Sugarcane. In: KOLE, C. et al. (Ed.). **Handbook of bioenergy crop plants**. Boca Raton: CRC Press, 2012. p. 523-561.

CANTARELLA, H.; ROSSETO, R. Fertilizers for sugarcane. In: CORTEZ, L. A. B. **Sugarcane bioethanol**: R&D for productivity and sustainability. São Paulo: Blucher, 2010. p. 405-422.

CANTARELLA, H.; ROSSETTO, R. **Fertilizer concerns.** Brasilia, DF: CGEE, 2012. 360p.

CASTOR, T. P.; HONG, G. T. **Extraction of fraction(s) from biomass, comprises contacting biomass with critical fluid suitable for liberation of structural biomass constituents**. US 6569640-B1, October 13 1998, May 27 2003.

CAVALCANTI, C. E. **The decisive role of supporting mechanisms for innovation**. Campinas: SABB, 2012.

CGEE – CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS. **Bioetanol combustível: uma oportunidade para ao Brasil**. Brasília, DF, 2009. 536p.

CGEE – CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS. **Sustainability of Sugarcane Bioenergy**. Brasilia, DF, 2012. 360p.

CHARLES, M. B. et al. Public policy and biofuels: the way forward? **Energy Policy**, Oxford, v. 35, n. 11, p. 5737–5746, 2007.

CLAY, D. E. et al. Corn yields and no-tillage affects carbon sequestration and carbon footprints. **Agronomy Journal**, Madison, v. 104, n. 3, p. 763-770, 2012.

CNT – CONFEDERAÇÃO NACIONAL DO TRANSPORTE. **CNT plan of transportation and logistics 2011**. Brasília, DF, 2011. 370p.

CONAB - COMPANHIA NACIONAL DE ABASTECIMENTO. **Séries históricas:** Brasil: produtos. Brasília, DF. Available at:<http://www.conab.gov.br/conteudos.php?a=1252&t=2>. Access on: March 27 2013.

CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. **Indicadores da Agropecuária:** dezembro e novembro, 2012, ano 21, n. 11/12. Brasília, DF, 2012. 53p.

CONSECANA – CONSELHO DOS PRODUTORES DE CANA, AÇÚCAR E ÁLCOOL DO ESTADO DE SÃO PAULO. **UnicaData**. São Paulo, 2013. Available at: <http://www.unicadata.com.br/listagem.php?idMn=61>. Access on: January 28 2013.

CORTEZ, L. A. B. **Sugarcane bioethanol**: R&D for productivity and sustainability. São Paulo: Blucher, 2010. 954p.

COSTA, P. N. **Azul+Verde**: Renewable Jet Fuel (Azul Airlines). Campinas: SABB, 2012.

CSIRO – COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION. **Flight path to Sustainable Aviation**. Sydney, 2011. 52p. Available at: <http://www.csiro.au/science/Sustainable-Aviation-Fuels-Road-Map. Access on: January 28 2013.

DE GRUYTER, W. **Biorefinery:** from biomass to chemicals and fuels. Berlin: Boston: [s.n.], 2012. 355p.

Defence Standards 91- 91. **Turbine Fuel, Kerosine Type, Jet A-1**, 2011.

DIAS, M. O. et al. Second generation ethanol in Brazil: can it compete with electricity production?. **Bioresource Technology**, Essex, v. 102, p. 8964-8971, Nov. 2011.

EBNER, C. Nova política para o combustível de aviação. **O Estado de S. Paulo**, São Paulo, 8 ago. 2012a. Available at: <http://www.estadao.com.br/noticias/impresso,nova-politica-para-o-combustivel-de-aviacao-,913065,0.htm>. Access on: January 28 2013.

EBNER, C. **Use of sustainable biofuels for aviation**: perspective 2020 (IATA). Campinas: SABB, 2012

ELLIOT, D. **Advancement of bio-oil utilization for refinery feedstock**. In: BIOENERGY RESEARCH SYMPOSIUM, 2010, Washington. **Proceedings...** Washington: Pacific Region Bioenergy Partnership, 2010. Available at: <http://www.pacificbiomass.org/documents/Elliott%20(C1).pdf>. Access on: September 3 2014.

EMBRAPA – EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Zoneamento agroecológico da cana-de-açúcar**. Brasília, DF, 2009. Available at: <https://www.embrapa.br/solos/busca-de-produtos-processos-e-servicos/-/produto-servico/1249/zoneamento-agroecologico-da-cana-de-acucar>. Access on: September 3 2014.

EMBRAPA – EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Zoneamento agroecológico do dendezeiro para as áreas desmatadas da Amazônia Legal.** Brasília, DF, 2010. Available at: <https://www.embrapa.br/busca-de-produtos-processos-e-servicos/-/produto-servico/1248/zoneamento-agroecologico-do-dendezeiro-para-as-areas-desmatadas-da-amazonia-legal>. Access on: July 29 2013.

EPE – EMPRESA DE PESQUISA ENERGÉTICA. **Brazilian energy balance:** year 2011. Brasília, DF, 2012. 282p.

EC – EUROPEAN COMISSION. **2 million tons per year**: a performing biofuels supply chain for EU aviation. Brussels, 2011. Available at: <http://ec.europa.eu/energy/technology/initiatives/doc/20110622_biofuels_flight_path_technical_paper.pdf>. Access on: January 28 2013.

EU - EUROPEAN UNION. **Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.** [S.l.]: Official Journal of the European Union, 2009. Available at: <http://faolex.fao.org/docs/pdf/eur88009.pdf>. Access on: January 28 2013.

FAVELA, R. **International market**: production and demand for aviation fuels. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16 2013.

FIESP – FEDERAÇÃO DAS INDÚSTRIAS DO ESTADO DE SÃO PAULO; ICONE - INSTITUTO DE ESTUDOS DO COMÉRCIO E NEGOCIAÇÕES INTERNACIONAIS. **Outlook Brasil 2022:** projeções para o agronegócio, São Paulo: FIESP: ICONE, 2012. 132p.

FOELKEL, C. **Eco-efficient management of woody forest residues from the eucalyptus plantation forestry**. [S.l] [s.n.], 2007. Available at: <http://www.eucalyptus.com.br/capitulos/ENG07.pdf>. Access on: January 28 2013.

FOLHA DE S. PAULO. Boeing terá centro de pesquisa e tecnologia no Brasil em 2012. **Folha de S. Paulo**, 3 abr. 2012. Available at: <http://folha.com/no1071070>. Access on: January 28 2013.

FRANCO, T. T. **Refining technologies**.Campinas: SABB, 2012

FREIRE, G. **Aviation Biofuel in Brazil**: challenges and perspectives. In: BRAZILIAN BIOENERGY SCIENCE AND TECHNOLOGY CONFERENCE, 1, 2011, Campos de Jordão: BBEST, 2011.

GALBE, M.; ZACCHI, G. Production of Ethanol from Lignocellulosic Material. In: CORTEZ, L. A. B. **Sugarcane bioethanol**: R&D for productivity and sustainability. São Paulo: Blucher, 2010. p. 697-716.

GOL. **A gol tem o orgulho de anunciar a realização do primeiro vôo comercial com biocombustível do Brasil**. [S.l]: Blog da Gol, 2013. Available at: </blog.voegol.com.br/index.php/gol/a-gol-tem-o-orgulho-de-anunciar-a-realizacao-do-primeiro-voo-comercial-com-biocombustivel-do-brasil/>. Access on: December 5 2013.

GOLDEMBERG, J. **An historical account of bioenergy production in Brazil**. In: BRAZILIAN BIOENERGY SCIENCE AND TECHNOLOGY CONFERENCE, 1, 2011, Campos de Jordão: BBEST, 2011.

GOLDEMBERG, J. Ethanol for a Sustainable Energy Future. **Science Magazine**, Washington, DC, v. 315, p. 808-810, Mar. 2007.

GOLDEMBERG, J. The Brazilian biofuels industry. **Biotechnology for Biofuels**, London, v. 1, n. 6, p. 1-7, 2008. Available at: <http://www.biotechnologyforbiofuels.com/content/pdf/1754-6834-1-6.pdf>. Access on: September 3 2014.

GOLDEMBERG, J.; COELHO, S. T.; GUARDABASSI, P. The sustainability of ethanol production from sugarcane. **Energy Policy**, Oxford, v. 36, n. 6, p. 2086-2097, 2008.

GOODWIN, P.; LYONS, G. Public attitudes to transport: interpreting the evidence. **Transportation Planning and Technology**, New York, v. 33, n. 1, p. 3-17, 2010.

GOPINATH, V. et al. Corynebacterium glutamicum as a potent biocatalyst for the bioconversion of pentose sugars to value-added products. **Applied Microbiology Biotechnology**, Berlin, v. 93, n. 1, p. 95-106, 2012, .

GRAALBIO. **GraalBio announces the first cellulosic ethanol plant in the Southern Hemisphere**. [S.l.] 2012. Available at: <http://graalbio.com/graalbio/wp-content/uploads/2012/02/First_cellulosic-ethanol_plant.pdf>. Access on: January 19 2013.

HENRICI-OLIVÉ, G.; OLIVÉ, S. The Fischer-Tropsch Synthesis: molecular weight distribution of primary products and reaction mechanism. **Angewandte Chemie International**, Weinheim, v. 15, n. 3, p. 136-141, 1976.

HUANG, W. D.; ZHANG, Y. H. P. Energy efficiency analysis: biomass-to-wheel efficiency related with biofuels production, fuel distribution and powertrain systems. **Plos One**, San Francisco, v. 6, p. 1-10, July 2011.

HUPE, J. Agreements and actions to reduce aviation emissions (ICAO Presentation). In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16 2013.

IATA – INTERNATIONAL AIR TRANSPORT ASSOCIATION. Global aviation and the fuel costs. SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16 2013.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Sidra**: Sistema IBGE de Recuperação Automática. Rio de Janeiro, 2013. Available at: <http://www.sidra.ibge.gov.br/ >. Access on: January 28 2013.

ICAO – INTERNATIONAL CIVIL AVIATION ORGANIZATION. **ICAO review**: sustainable alternative fuels for aviation. Montréal, 2011. 56p. Available at: <http://www.icao.int/environmental-protection/Documents/SUSTAF%20Review%5B2%5D.pdf>. Access on: January 28 2013.

ICAO – INTERNATIOAL CIVIL AVIATION ORGANIZATION. **ICAO Global Framework for Aviation Alternative Fuels**. Montréal, 2013. Available at: <http://icao.int/environmental-protection/GFAAF/Pages/default.aspx>. Access on: January 28 2013.

ICONE – INSTITUTE FOR INTERNATIONAL TRADE NEGOCIATION. **Benchmark of cane-derived renewable jet fuel against major sustainability standards**. São Paulo, 2012. 73p. Available at: <http://www.iconebrasil.org.br/arquivos/noticia/2593.pdf>. Access on: January 28 2013.

IEA - INTERNATIONAL ENERGY AGENCY. **Technology roadmap**: biofuels for transport. Paris, 2010. 56p. Available at: <http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf. Access on: September 4 2014.

IEA – INTERNATIONAL ENERGY AGENCY. **Oil Market Report**: annual statistical supplement. Paris, 2011. 44p. Available at: <http://omrpublic.iea.org/omrarchive/sup2011.pdf>. Access on: January 28 2013.

IUCN – INTERNATIONAL UNION FOR CONSERVATION OF NATURE. **Betting on best quality**: a comparison of the quality and level of assurance of sustainability standards for biomass, soy and palmoil. Amsterdam, 2013. Available at: <http://cmsdata.iucn.org/downloads/betting_on_best_quality.pdf>. Access on: September 29 2014.

JANK, M. S. **The biofuel industry perspective**: sugarcane. Campinas: SABB, 2012

JENKINS, R. W. et al. Potential renewable oxygenated biofuels for the aviation and road transport sectors. **Fuel**, Bath, v. 103, p. 593-599, 2013.

KAMM, B. et al. Biorefinery systems: an overview. In: KAMM, B.; GRUBER, P. C.; KAMM, M. (Ed.). **Biorefineries-industrial processes and products**. Weinheim: Wiley-VCH, 2006. p. 265.

KANER, S. et al. **Facilitor's guide to participatory decision-making**. 2. ed. New York: John-Wiley & Sons, 2007. 432 p.

KANITZ, J.; KESSELRING, B. **Treatment of solid and liq. organic waste producing bio-gas and compos such as cooked raw food residues, animal excrements, and wastes from paper production**. Patent, Patent Assignee: ECOLAB AG; BEG BIOENERGIE GMBH, 2002 – n.: JP3340437-B2.

KANT, P.; WU, S. The extraordinary collapse of Jatropha as a global biofuel. **Environmental Science & Technology**, Iowa City, v. 45, p. 7114-7225, 2011.

KARIMI, E. et al. Red mud as a catalyst for the upgrading of hemp-seed pyrolysis bio-oil. **Energy & Fuels**, Washington, DC, v. 24, n. 12, p. 6586-6600, 2011. Available at: <http://pubs.acs.org/doi/abs/10.1021/ef101154d?journalCode=enfuem>. Access on: September 4 2014.

KAULL, B. K. et al. H**ydroprocessing feedstock containing lipid material to produce transportation fuel.** EP 2496667-A2, November 4 2009, September 12 2012.

KLERK, A. D. Fischer–Tropsch fuels refinery design. **Energy and Environmental Science**, Cambridge, v. 4, p. 1177-1205, 2011.

KOIZUMI, T. The Japanese biofuel program: developments and perspectives. **Journal of Cleaner Production**, Oxford, v. 40, p. 57-61, Feb. 2013.

KOSKINEN, P.; TANNER, R. **An integrated process for producing biofuels**. EP 2468875-A1, December 22 2010, June 27 2012.

KOVACS, K.; MACRELLI, S.; SZAKACS, G. Enzymatic hydrolysis of steam-pretreated lignocellulosic materials with Trichoderma atroviride enzymes produced in-house. **Biotechnology Biofuels**, London, v. 2, n. 14, p. 1-11, 2009.

KUMAR, A. et al. Thermochemical biomass gasification: a review of the current status of the technology. **Energies**, Basel, v. 2, n. 3, p. 556-581, 2009.

KUMAR, S.; CHAUBE, A.; JAIN, S .K. Critical review of jatropha biodiesel promotion policies in India. **Energy Policy**, Oxford, v. 41, n. C, p. 775-781, 2012.

KURIYAMA, H.; KOBAYASHI, H.; ISHIBASHI, H. **Process for continuously fermenting saccharides to produce alcohol using a flocculating microorganism.** CA 2054860-A1, November 9 1990, May 10 1992.

LA ROVERE, E. L.; PEREIRA, A. S.; SIMOES, A. F. Biofuels and sustainable energy development in Brazil. **World Development**, Oxford, v. 39, n. 6, p. 1026-1036, 2011.

LAM, M. K.; LEE, K. T.; MOHAMED, A. R. Current status and challenges on microalgae-based carbon capture. **International Journal of Greenhouse Gas Control**, Amsterdam, v. 10, p. 456-469, Dec. 2012.

Lanzatech. Presentation during 3rd Sustainable Aviation Biofuels for Brazil Project Workshop, July 11th and 12th, Unicamp, Campinas, Brazil, 2012. Available at:<www.nipeunicamp.org.br/sabb>. Access on: January 28th 2013.

LEAL, M. R. L. V., NOGUEIRA, L. A. H., CORTEZ, L. A. B. Land demand for ethanol production. **Applied Energy**, Amsterdam, v. 102, p. 266-271, Feb. 2013.

LEITE, R. C. D. et al. Can Brazil replace 5% of the 2025 gasoline world demand with ethanol?. **Energy**, Oxford, v. 34, n. 5, p. 655-661, 2009.

LUQUE, R. et al. Design and development of catalysts for Biomass-To-Liquid-Fischer–Tropsch (BTL-FT) processes for biofuels production. **Energy and Environmental Science**, Cambridge, v. 5, p. 5186-5202, 2012.

LYONS, W. **Aviation and sustainable biofuel**. Campinas: SABB, 2012.

MACEDO, I. C., SEABRA, J. E. A.; SILVA J. E. A. R. Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: the 2005/2006 averages and a prediction for 2020. **Biomass and Bioenergy**, Oxford, v. 32, p. 582-595, 2008. Available at: <http://cenbio.iee.usp.br/download/publicacoes/macedo_et_al-balance2020.pdf>. Access on: September 4 2014.

MADSEN, A. T. et al. Hydrodeoxygenation of waste fat for diesel production: Study on model feed with Pt/alumina catalyst. **Fuel**, Bath, v. 90, n. 11, p. 3433-3438, 2011.

MAGALHÃES, P. S. G. et al. **Agro-industrial technological paths**. Brasília: CGEE, 2012, 360p.

MANIATIS, K.; WEITZ, M.; ZSCHOCKE, A. **Workshop**: achieving 2 million tons of biofuels use in aviation by 2020. Brussels: EU, 2011. Available at: <http://ec.europa.eu/energy/technology/events/2011_05_18_biofuels_in_aviation_en.htm>. Access on: August 17 2013.

MAPA – MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO. **Produção brasileira em números**. Brasília, DF, 2012. Available at: <http://agricultura.gov.br/arq_editor/file/vegetal/Estatistica/2005.htm>. Access on: January 28 2013.

MAURICE, L. The importance of a roadmap for aviation alternative fuels. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16th, 2013.

MCFARLANE, R. **Sustainable aviation fuels**: a global perspective. Campinas: SABB, 2012.

MILLER, S. J. **Efficiently making biolubricants and biofuels from vegetable or crop oils; involves separation of saturated, monounsaturated and polyunsaturated fatty acids derived from renewable triglycerides, and using some to make biodiesel or ester biolubricants and others to make paraffins.** US 7815694-B2, September 27 2007, October 19 2010.

MODENBACH, A. A.; NOKES, S. E. The use of high-solids loadings in biomass pretreatment-a review. **Biotechnology and Bioengineering**, New York, v. 109, n. 6, p. 1430-1442, 2012.

MOHAN, D.; PITTMAN, C. U.; STEELE, P. H. Pyrolysis of wood/biomass for bio-oil: a critical review. **Energy Fuels**, Washington, DC, v. 20, n. 2, p. 848-889, 2006.

MORAES, M. A. F. D; NASSAR, A. **Main findings**. Campinas: SABB, 2012.

MORAIS, R.F. et al. Elephant grass genotypes for bioenergy production by direct biomass combustion. **Pesquisa Agropecuaria Brasileira**, Brasília, DF, v. 44, n. 2, p. 133-140, 2009.

MOREIRA, R. **The role of the regulator for aviation biofuels**. Campinas: SABB, 2012.

MOSIER, N. et al. Features of promising technologies for pretreatment of lignocellulosic biomass. **Bioresource Technology**, Essex, v. 96, n. 6, p. 673-686, 2005.

MOSER, B. R. Camelina (*Camelina sativa* L.) oil as a biofuels feedstock: Golden opportunity or false hope. **Lipid Technology**, Weinhheim, v. 22, n. 12, p. 270-270, 2010.

MUBONDERI, J. **Jatropha:** the broom of poverty; mith or reality: a critical analysis of the Zimbabwean jatropha programme in Mutoko district. [S.l]: PISCES: UKAid, 2012. Available at: <http://www.pisces.or.ke/sites/default/files/The%20Broom%20of%20Poverty%20Working%20Brief%20SINGLE%20PAGES.pdf>. Access on: September 4 2014.

NAHUZ, M. A. R. From the forest to the processing plant: the logistic of wood in Brazil. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: January 28 2013.

NASSAR, A. M; CANTARELLA, H. **Competitiveness and basic indicators of available feedstocks**. Campinas: SABB, 2012a.

NASSAR, A. M.; CANTARELLA, H. **Main findings**. Campinas: SABB, 2012b.

NASSAR, A. M.; CANTARELLA, H. **Main challenges in research sustainability, feedstock, processing and logistics**: feedstocks. Campinas: SABB, 2012c.

NASSAR, A. M. et al. **Simulating land use and agriculture expansion in Brazil**: food, energy, agro-industrial and environmental impacts. São Paulo, 2011. Relatório científico final. Available at: <http://www.iconebrasil.com.br/datafiles/publicacoes/artigos/2002/simulating_land_use_and_agriculture_expansion_in_brazil_0902.pdf>. Access on: September 4 2014.

NASSAR, A.; MOREIRA, M. **Evidences on sugarcane expansion and agricultural land use changes in Brazil**. São Paulo: ICONE, 2013. Report. Available at:< http://sugarcane.org/resource-library/studies/evidences_on_sugarcane_expansion_and_agricultural_land_use_changes_in_brazil_1206.pdf>. Access on: September 5 2013.

NEVES, M. F. et al. **Food and fuel**: the example of Brazil. Wageningen: Wageningen Academic Publishers, 2011. 148p.

NGUYEN, T. L. T.; GHEEWALA, S. H.; GARIVAIT, S. Full chain energy analysis of fuel ethanol from cassava in Thailand. **Environmental Science & Technology**, Iowa City, v. 41, n. 11, p. 4135-4142, 2007.

NIGRO, F. E. B. **The Brazilian/São Paulo perspectives for renewable fuels**. Campinas: SABB, 2012.

NOGUEIRA, L. A. H. Does Biodiesel make sense? **Energy**, Oxford, v. 36, n. 6, p. 3619-3944, 2011.

NOGUEIRA, L. A. H.; CAPAZ, R. S. Biofuels in Brazil: evolution, achievements and perspectives on food security. **Global Food Security**, New York, v. 2, n. 2, p. 117-125, 2013.

NRDC – NATURAL RESOURCE DEFENSE COUNCIL. **Biofuel sustainability performance guideline**. New York, 2014. Available at: <http://www.nrdc.org/energy/files/biofuels-sustainability-certification-report.pdf>. Access on: September 29 2014.

NUNES, P. B. Soybeans. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: January 28 2013.

NYGREN, E.; KJELL, A.; HOOK, M. Aviation fuel and future oil production scenarios. **Energy Policy**, Oxford, v. 37, n. 10, p. 4003-4010, 2009.

OAG. **The European Union Emission Trading Scheme**: market intelligence report. London, 2012.

O ESTADO DE S. PAULO. Etanolduto começa a funcionar em março. **O Estado de S. Paulo**, São Paulo, Nov. 5 2013. Available at: <http://economia.estadao.com.br/noticias/geral,etanolduto-comeca-a-funcionar-em-marco,133587e>. Access on: January 28 2013.

OLAH, G. A. et al. **Selective oxidative conversion of methane to methanol, dimethyl ether and derived products**. EP 1871732-B1, April 15 2005, July 18 2012.

OPENSHAW, K. A review of Jatropha curcas: an oil plant of unfulfilled promise. **Biomass and Bioenergy**, Oxford, v. 19, n. 1, p. 1-15, 2000.

OVALLES, C.; ROGEL, E.; MOIR, M. **Method for predicting reactivity of a hydrocarbon-containing feedstock for hydroprocessing**. WO 2011032125-A3, September 14 2009, July 21 2011.

OXFORD ECONOMICS. **Economic benefits from air transport in Brazil**. Oxford, 2011. 28p. Available at: <http://www.benefitsofaviation.aero/Documents/Benefits-of-Aviation-Brazil-2011.pdf>. Access on: January 28 2013.

PARGHI, K. D.; SATAM, J. R.; JAYARAM, R. V. Silica supported heteropolyacid catalyzed dehydration of aldoximes to nitriles and alcohols to alkenes. **Green Chemestry Letters and Reviews**, Abingdon, v. 4, n. 2, p. 143-149, 2011.

PECEGE – PROGRAMA DE EDUCAÇÃO CONTINUADA EM ECONOMIA E GESTÃO DE EMPRESAS. **Custo de produção de cana-de-açúcar, açúcar e etanol no Brasil:** acompanhamento da safra 2011/2012, Centro-Sul. Piracicaba: Esalq: Pecege, 2012. 58 p. Relatório apresentado à Confederação da Agricultura e Pecuária do Brasil.

PETROBRAS – PETRÓLEO BRASILEIRO S.A. **Plano de Negócios 2011-2015**. Brasília, DF, 2012.

PINTO JR., H. Q. **The development of news fuels in Brazil**: the role of the regulator. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 11., 2012, Rio de Janeiro.

Proceedings... Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16 2013.

RENEWABLE JET FUELS. **Industry background**. Washington, DC. Available at: <http://renewablejetfuels.org/what-we-do/the-basics>. Access on: January 24 2013.

RODRIGUES FILHO, S. Commercialization of jet biofuel and its impact on the distribution system: jet fuel taxes in Brazil. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: January 28 2013.

RODRIGUEZ, L. C. E. Wood: logistics in Brazil: topics for debate. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: January 28 2013.

ROSILLO-CALLE, F. Food versus fuel: toward a new paradigm: the need for a holistic approach. **ISRN Renewable Energy**, New York, v. 2012, p. 1-15, 2012.

ROSSETTO, R. et al. Fertility maintenance and soil recovery in sugarcane crop. In: CORTEZ, L. A. B. **Sugarcane Bioethanol**: R&D for productivity and sustainability. São Paulo: Blucher, 2010. p. 381-403.

RSB – ROUNDTABLE ON SUSTAINABLE BIOMATERIALS. **RSB principles and criteria for sustainable biofuel production**. Geneva, 2010. Available at: <http://rsb.org/pdfs/standards/11-03-08%20RSB%20PCs%20Version%202.1.pdf>. Access on: September 29 2014.

RUMIZEN, M. **Alternative jet fuel approval**. Gaithersburg: NIST, 2012.

SAFN – SUSTAINABLE AVIATION FUELS NORTHWEST. **Sustainable aviation fuels northwest**: powering next generation of flight, report. [S.l] 2011. Available at: <http://www.wedc.wa.gov/Download%20files/SAFN_2011Report.pdf>. Access on: January 3 2013.

SCHUCHARDT, U. **Main findings**. Campinas: SABB, 2012.

SCHUMMAN, R. SINDICOM: Logistics & Support. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: January 28 2013.

SFB – SERVIÇO FLORESTAL BRASILEIRO. **Florestas do Brasil em resumo**: dados de 2005-2010. Brasília, DF, 2010. 152p.

SMIL, V. Phosphorus in the environment: natural flows and human interferences. **Annual Review of Energy and the Environment**, Palo Alto, v. 25, p. 53-88, 2000.

SOLAZYME. Solazyme accelerates U.S. commercialization for renewable oils production with Archer-Daniels-Midland Company Agreement. **Solazyme**, San Francisco, Nov. 14, 2012. Availabe at: <http://investors.solazyme.com/releasedetail.cfm?ReleaseID=721368>. Access on: January 19 2013.

SOLAZYME. Solazyme Bunge Renewable Oils Joint Venture Receives Funding Approval from Brazilian Development Bank. BNDES to provide approximately USD $120 million in project financing to support sugar-to-oil production facility in Brazil. **Solazyme**, San Francisco, Jan. 16 2013. Available at: <http://www.businesswire.com/news/home/20130116006583/en/ Solazyme-Bunge-Renewable-Oils-Joint-Venture-Receives#.VAi_KcVdUgQ>. Access on: January 19 2013.

STREET, J. et al. Gasoline-range hydrocarbon production using biomass derived synthesis gas over Mo/H(+)ZSM-5. **Fuel**, Bath, v. 96, p. 239-249, 2012.

SUN, S. et al. Direct conversion of bio-ethanol to isobutene on nanosized ZnxZryOz mixed oxides with balanced acid-base sites. **Journal of the American Chemical Society**, Washington, DC, v. 133, n. 29, p. 11096-11099, 2011.

SWAFEA – SUSTAINABLE WAY FOR ALTERNATIVE FUELS AND ENERGY FOR AVIATION. **Environmental impact analysis report**. European Comission, 2011, 144p. Available at: <http://www.swafea.eu/LinkClick.aspx?fileticket=BL6eHW8QfKo%3D&tabid=77>. Access on: January 28 2013.

THE ECONOMIST. What happened to biofuels?. **The Economist,** London, Sep. 7 2013. Available at: <http://www.economist.com/news/technology-quarterly/21584452-energy-technology-making-large-amounts-fuel-organic-matter-has-proved-be>. Access on: September 7 2013.

TIJMENSEN, M. J. A.; FAAIJ, A. P. C. Exploration of the possibilities for production of Fischer-Tropsch liquids and power via biomass gasification. **Biomass and Bioenergy**, Oxford, v. 23, p. 129-152, 2002.

UNICA – UNIÃO DA INDÚSTRIA DE CANA-DE-AÇÚCAR. **UnicaData**. Piracicaba, 2014. Available at: <http://www.unicadata.com.br/>. Access on: September 29 2014.

VAMVUKA, D. Bio-oil, solid and gaseous biofuels from biomass pyrolysis processes: an overview. **International Journal of Energy Resource**, Chicester, v. 35, p. 835-862, 2011.

WANG, Z.; CALDERON, M. M.; LU, Y. Lifecycle assessment of the economic, environmental and energy performance of Jatropha curcas L. biodiesel in China. **Biomass and Bioenergy**, Oxford, v. 35, p. 2893-2902, 2011.

WILSON III, G.R. Regulatory requirements on development of renewable alternative fuels for aviation: requirements aviation fuels. In: SEMINÁRIO INTERNACIONAL DE COMBUSTÍVEIS DE AVIAÇÃO, 6., 2012, Rio de Janeiro. **Proceedings...** Rio de Janeiro: ANP, 2012. Available at: <http://www.anp.gov.br/?pg=60724>. Access on: February 16 2013.

WWF – WORLD WIDE FUND FOR NATURE. **Search for sustainability**: comparative analysis of certification schemes for biomass used for the production of biofuels. Düsseldorf, 2013. Available at: <http://d2ouvy59p0dg6k.cloudfront.net/downloads/wwf_searching_for_sustainability_2013_2.pdf>. Access on: September 29 2014.

ZHANG, J. et al. Upgrading of bio-oil over bifunctional catalysts in supercritical monoalcohols. **Energy Fuels**, Washington, DC, v. 26, p. 2990-2995, 2012.

GLOSSARY

A	
ABNT	“Brazilian Association of Technical Standards”.
ABRABA	“Brazilian Alliance for Aviation Biofuels”.
ACA	“ACA Associates”. The new name for Airline Capital Associates, Inc. Company working on consulting and financial advisory, specialize in the commercial aviation industry, which includes manufacturers, airlines, airports, after-market support companies, and ground service companies.
AIAB	“Aerospace Industries Association of Brazil”. National trade association that represents the Brazilian aerospace industries.
Alternative fuels	Non-conventional fuels (including biofuels such as biodiesel or ethanol, hydrogen, electricity-storing batteries, fuel cells), often with improved environmental footprints, that are derived from non-petroleum sources.
Amyris	Integrated renewable products company providing sustainable alternatives to a broad range of petroleum-sourced products.
ANAC	“National Civil Aviation Agency” (Brazil)
Andritz	Company working on supplying of plants and services for the hydropower, pulp and paper, metals, and other specialized industries.
ANFAVEA	“Brazilian Automotive Industry Association”
ANP	“Brazilian National Agency of Petroleum, Natural Gas and Biofuels”.
ANTAQ	“National Agency for Waterway Transportation” (Brazil)
ANTT	“National Transportation Agency” (Brazil)
APTA	“Agência Paulista de Tecnologia dos Agronegócios” from São Paulo State Government.
APTTA	“Associação Portuguesa de Transporte e Tráfego Aéreo”
ARS	“Agriculture Research Service”.
ASTM International	Originally known as the American Society for Testing and Materials (ASTM). A voluntary standards development organizations. ASTM International specifications are used for the certification of jet fuel.
AZUL	Brazilian airline company.
B	
Barrel of Oil Equivalent	A term used to summarize the amount of energy that is equivalent to the amount of energy found in a barrel of crude oil. Also known as Crude Oil Equivalent.
BASF	German private company working on chemicals.
BAYER	German private company working on chemicals and pharmaceuticals.
Bioeca	Company working on producing sustainable raw materials for biofuels (second generation), mainly aviation bio-kerosene.
Biofuel	Renewable fuels derived from biological materials that can be regenerated. This distinguishes them from fossil fuels, which are considered nonrenewable. Examples of biofuels for ground transport are ethanol, methanol, and biodiesel. Biofuels compatible with aviation can include Fischer-Tropsch or hydrotreated jet fuel made from plant or animal sources or hydrocarbons synthesized by genetically modified organisms (synthetic biology).

Byogy Renewables	Company working on producing advanced biofuels, namely jet fuel and gasoline from any source of bio ethanol.
Biomass	Biomass is any mass that has been produced by the growth and resource use of living organisms; therefore any plant, animal, or bacterial material is biomass (e.g., leaves, wood chips, algae).
Bio-oil	Liquid product obtained in fast pyrolysis or solvent liquefaction of biomass. Bio-oils contain large amounts of oxygen and needs up-grading.
Bio-char	Solid product obtained in fast pyrolysis or solvent liquefaction of biomass. Bio-char has a high carbon content and can be used as active carbon or for soil refinement or for gasification.
BNDES	"Brazilian Development Bank" (Brazilian bank).
BOE	"Barrel of Oil Equivalent".
BOEING	The Boeing Company, a global aerospace and defense company that manufactures commercial jetliners and defense, space and security systems.
BTL	Biomass to Liquid (BTL) is the process to produce liquid biofuels from biomass, usually referring to gasification and Fischer-Tropsch (FT) synthesis.
C	
CAAFI	"Commercial Aviation Alternative Fuels Initiative"
Camelina Company	American private company working on manufacturing and marketing of fuel and chemicals from Camelina
CANAVIALLIS	Brazilian private company working on genetic breeding research for sugarcane and sorghum
Carbon capture and sequestration	A process of capturing carbon dioxide emissions to prevent them from going into the atmosphere, and then storing them permanently. A commonly discussed strategy is to store captured CO_2 by pumping it underground into geological formations. There are also discussion of biological capture and sequestration in trees, algae etc. In both cases "permanency" of solution is yet to be proven.
Carbon dioxide	Enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
Carbon neutral growth	An industry, sector, or company continues to expand its activities without further increases in greenhouse gas emission.
Catalysis	The process in which the rate of a chemical reaction is either increased or decreased by means of a chemical substance.
Catalyst	A substance that increases the rate of a chemical reaction without itself undergoing any change.
Cellulose	The structural component of the primary cell wall of green plants, many forms of algae and the oomycetes. It is made up of cross-linked sugar molecules and is very difficult to break down. A "cellulosic" biofuel production process would degrade cellulose sufficiently to make the sugars accessible for further processing.
CENBIO	"Brazilian Reference Center on Biomass".
CEPID	"Research, Innovation and Dissemination Centers" (Fapesp Research Program).
Certification	Refers to the confirmation of certain characteristics of an object, person, or organization.
CH4	"Methane".

CIAT	"International Center for Tropical Agriculture"
CLEEN	"Continuous Low Energy Emissions and Noise".
CNT	"National Confederation of Transportation"
CO	"Carbon monoxide".
CO_2	"Carbon dioxide".
Coal to Liquid (fuels)	A process referred to as coal liquefaction – allows coal to be utilized as an alternative to oil. There are two different methods for converting coal into liquid fuels:
	Direct liquefaction works by dissolving the coal in a solvent at high temperature and pressure. This process is highly efficient, but the liquid products require further refining to achieve high grade fuel characteristics.
	Indirect liquefaction gasifies the coal to form a 'syngas' (a mixture of hydrogen and carbon monoxide). The syngas is then condensed over a catalyst – the 'Fischer-Tropsch' process – to produce high quality, ultra-clean products.
Coal/Biomass to Liquid (fuels)	A process by which coal and biomass are turned into synthetic hydrocarbons, often via Fischer-Tropsch synthesis.
Continuous Low Energy Emissions and Noise	Program to develop and foster industry acceptance of new technologies that reduce environmental impacts.
Crack Spread	The difference between crude oil and refined petroleum product prices, when expressed in similar units, is known as the crack spread. For example, if crude oil costs $60 per barrel and jet fuel costs $75 per barrel, the jet fuel crack spread is $15 per barrel.
Cracking (of fuel)	Term used in the oil refining industry, meaning to "crack" crude oil, which is to break down the long-chain hydrocarbons in the crude oil into shorter chains. Also used with regard to the breaking of long-chain fatty acid derivatives (usually C18-C22) or synthetic waxes (e.g., from Fischer-Tropsch) to the jet fuel range (C8-C14).
Crude oil	A mixture of hydrocarbons that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface-separating facilities. The U.S. benchmark for crude oil prices is West Texas Intermediate (WTI), measured in Cushing, Oklahoma.
Crude Oil Equivalent	A term used to summarize the amount of energy that is equivalent to the amount of energy found in a barrel of crude oil. Also known as Barrel of Oil Equivalent.
CSIRO	"Commonwealth Scientific and Industrial Research Organization".
CTBE	"Brazilian Bioethanol Science and Technology Laboratory".
CTC	"Sugarcane Research Center".
CTL	"Coal to Liquid".
D	
DCTA	"Department of Aerospace Science and Technology (Brazilian Ministry of Defense)
DEDINI	Brazilian private company working on equipment development and supply of complete sugarcane plants (sugarcane mills).
Drop-in jet biofuel	A substitute for conventional jet fuel, that is completely interchangeable and compatible with conventional jet fuel. It can be a neat biofuel or a blend of biofuel and conventional fuel according to ASTM specifications. A drop-in biofuel does not require adaptation of the aircraft/engine fuel system or the fuel distribution network, and can be used "as is" on currently flying turbine-powered aircraft.

E	
EMBRAER	Brazilian private company working on aircraft manufacturer and systems for defense and security segments
EMBRAPA	“Brazilian Agricultural Research Corporation”.
EMBRAPA ALGODÃO	“Brazilian Agricultural Research Corporation – Cotton Center”.
EMBRAPA BIOENERGY	“Brazilian Agricultural Research Corporation – Bionergy Center”.
EMBRAPA SOJA	“Brazilian Agricultural Research Corporation – Soybean Center”.
EPAGRI	“Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina” from Santa Catarina State Government.
EPE	“Brazilian Enterprise for Energy Research”
EPFL	“École Polytechnique Fédérale de Lausanne”
EPUSP	“Polytechnic School of University of São Paulo”
Ergostech	Brazilian company working on renewable energy solutions.
ESALQ	“Luiz de Queiroz College of Agriculture” from USP.
ESALQ-LOG	“Group of Research and Extension in Agroindustrial Logistics” from ESALQ
EtOH	The molecular formula for Ethanol is C_2H_5OH. Ethanol is often abbreviated as EtOH, using the common organic chemistry notation of representing the ethyl group (C_2H_5) with Et and the Hydroxyl group with OH. Ethanol is a product of fermentation. However, it is not compatible with existing turbine-powered aircraft or infrastructure.
F	
FAME	“Fatty Acid Methyl Ester”
FAPEMIG	“Minas Gerais State Research Foundation” from Minas Gerais State Government.
FAPESP	“São Paulo Research Foundation” from São Paulo State Government.
Fast pyrolysis	Pyrolysis with high heating rate, normally done in a fluidized bed.
Fatty Acid Methyl Ester	More commonly referred to as biodiesel. This is traditional biodiesel, produced by processing raw vegetable oil or animal fats through a chemical process called transesterification. While it is used in diesel surface vehicles, FAME is not considered a suitable “drop in” fuel for jet aircraft.
Fatty acids	Organic acids from which fats and oils are made. These can be used as feedstocks for HRJ fuels.
FBO	“Fixed-Based Operator”.
FEA	“School of Food Engineering” from UNICAMP.
FEAGRI	“School of Agricultural Engineering” from UNICAMP.
Feedstock	Raw material required for an industrial process and more specifically for the production of an alternative fuel.
FEQ	“School of Chemical Engineering” from UNICAMP.
Fermentation	Any of a group of chemical reactions induced by living or nonliving ferments that split complex organic compounds into relatively simple substances. Often used to refer to sugar processing by microorganisms to form ethanol or, in the case of advanced fermentation, hydrocarbons or other synthetic chemicals.

Fermentec	Brazilian private company working on innovation, development technologies and consulting services for the production of sugar, ethanol and energy for bioenergy plants and distilleries.
Fermented Renewable Jet	A biofuel created by a synthetic biology process in which metabolic processes involved in fermentation have been co-opted by genetically modifying organisms to produce hydrocarbons in place of ethanol.
FIEMG	"Federation of Industries of Minas Gerais"
FINEP	"Study and Project Finance Agency" from MCTI.
Fischer-Tropsch	Is a catalyzed chemical reaction in which synthesis gas, a mixture of carbon monoxide and hydrogen, is converted into liquid hydrocarbons of various forms. Named for German researchers Franz Fischer and Hans Tropsch.
Fixed-Based Operator	The primary provider of services to general aviation aircraft and operators located at or adjacent to an airport. General aviation refers to all flights other than military and scheduled airline and regular cargo flights, both private and commercial.
Fluorinated Gases	Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").
Fossil Fuels	Any naturally occurring organic fuel formed in the Earth's crust, such as petroleum, coal and natural gas. Formed by fossilization of organic material deposited by decaying plant/animal matter.
FRJ	"Fermented Renewable Jet".
FRL	"Fuel Readiness Level". A scale developed by CAAFI that provides a way to objectively measure how close a particular alternative fuel or feedstock is to successful deployment for jet fuel production.
FSA	"Fuel Supply Agreement".
FT Fuel	Fuel produced by the Fischer-Tropsch method.
FT Process	Fischer-Tropsch.
Fuel Farm	Holding place where fuel resides.
Fuel supply agreement	A document that contains details on an agreement between a seller and buyer for a commitment to sell and to purchase fuel. The agreement will contain name of buyer, the seller, term, product specification, volume, price, payment terms, delivery points, contacts and any other terms and conditions related to the transaction.
FUPEF	See "Forest Research Foundation of Parana".
G	
Gasification	It is a manufacturing process that converts any material containing carbon—such as coal, petroleum coke (petcoke), or biomass—into synthesis gas (syngas).
GE/GRC	"General Electric Company – Global Research Center"
General aviation	A term used to describe all non-military and non-airline flying, encompassing everything from recreational aircraft to experimental aircraft to privately owned and operated business jets. General aviation flies according to FAA's part 91 or 135 rules.
GHG	Greenhouse Gases
GIS	Geographic Information System

Global warming potential	The cumulative radiative forcing effects of a gas over a specified time horizon resulting from the emission of a unit mass of gas relative to a reference gas. Used to compare different green-house-gases with each other on a relative basis.
GOL	Brazilian air transport company.
GPS	Global Positioning System
Greenhouse gases (GHG)	Gases that trap heat in the atmosphere. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide, methane, nitrous oxide and fluorinated gases.
GWP	"global warming potential".
H	
H_2O	Water (solid, liquid or vapor).
HAPs	See "hazardous air pollutants"
Hazardous air pollutants	Defined in the Clean Air Act (1990) as air pollutants that are known to cause or may reasonably be anticipated to cause adverse effects to human health or adverse environmental effects. The list of pollutants is available online and comprises approximately 200 individual compounds.
HEFA	Hydroprocessing of Esters and Fatty Acids
HRJ	Hydrotreated Renewable Jet fuel.
HCVA	High Conservation Value Area
Hydrocarbons	Substances containing only hydrogen and carbon. Fossil fuels are made up of hydrocarbons. As are synthetic drop-in jet fuels.
Hydroprocessing	Any of several chemical engineering processes including hydrogenation, hydrocracking and hydrotreating, especially as part of oil refining.
Hydrotreating	Process that removes sulfur and nitrogen in petroleum refineries to improve the quality of gasoline, jet fuels and diesel fuel.
I	
IAC	"Agronomic Institute of Campinas" from São Paulo State Government.
IAPAR	"Agronomic Institute of Parana" from Paraná State Government.
IATA	"International Air Transport Association"
IB	"Biology Institute" from Unicamp.
IBGE	"Brazilian Institute of Geography and Statistics" from Federal Government
ICAO	"International Civil Aviation Organization".
ICONE	"Institute for International Trade Negotiations".
ICT	Information and Communication Technologies
IFAD	"International Fund for Agricultural Development "
INPE	"National Institute for Space Research" (Brazil)
Intergovernmental Panel on Climate Change	The leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences.
IPCC	"Intergovernmental Panel on Climate Change".
IQ	"Institute of Chemistry" from UNICAMP

ITA	"Technological Institute of Aeronautics" from DCTA
J	
Jet A	Jet A is a kerosene type of fuel, produced to an American Society for Testing and Materials (ASTM) specification and normally only available in the U.S.A. It has the same flash point as Jet A-1 but a higher freeze point maximum (-40°C). It is supplied against the ASTM D1655 (Jet A) specification.
Jet fuel	The term includes kerosene-type jet fuel and naphtha-type jet fuel. Kerosene-type jet fuel is used primarily for commercial turbojet and turboprop aircraft engines. Naphtha-type jet fuel has been largely phased out but was used primarily for military turbojet and turboprop aircraft engines.
JIRCAS	"Japan International Research Center for Agricultural Sciences".
Joule	A unit of work or energy symbolized by the letter "J".
K	
Kyoto Protocol	An international agreement linked to the United Nations Framework Convention on Climate Change. The Kyoto Protocol sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions .
L	
Land use change	A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct, human-induced land use, land-use change and forestry activities. This term can also refer to indirect land use changes that may occur as a result of changes in resource use and consumption patterns (i.e., potential land-use change in other locations due to use of a local crop for biofuel production).
Lanzatech	American private company working on development and commercialization proprietary technologies for the production of low-carbon fuels.
LCA	Life cycle analyses (LCA) looks at the whole picture of how a fuel is made, from "cradle to grave." In the case of biofuels generally refers to greenhouse gas emissions or CO_2 emissions from initiation of feedstock production to combustion of the fuel in a vehicle.
Life	"Life Technologies". LIFE is a global biotechnology company providing complete Synthetic Biology solutions to areas such as Biofuels, Agricultural Biotechnology, Bio-based Chemicals, Industrial Enzymes, Biocontrols, Life Science Research, Pharma, Vaccines and Antibodies.
Limited liability company	A business structure similar to a corporation, in which owners have limited personal liability for the debts and actions of the LLC. Other features of LLCs are more like a partnership, providing management flexibility and the benefit of pass-through taxation.
Liquefaction	A process by which natural gas is converted into a liquid. Also a process by which coal is converted into synthetic fuels. Can also refer to biomass liquefaction at high pressure and moderate temperature that results in the production of low-oxygen bio-oil, which can be used as, or further refined into, hydrocarbon fuel.
LLC	"Limited Liability Company".
LTO	Landing and take-off emissions (LTO) All aircraft activities that take place at altitudes under 914 meters (3,000 feet), including taxi-in and -out, take-off, climb-out and approach-landing.
Lumin Weyerhaeuser	Company working on sustainable plywood production from pine and eucalyptus.

M	
MAPA	"Ministry of Agriculture, Livestock and Supply" (Brazil)
MCTI	"Ministry of Science, Technology and Innovation" (Brazil)
MJ	measurement unit for energy.
Megaton (i.e., of CO_2)	One million tons.
Memorandum of Understanding	A document describing a bilateral or multilateral agreement between parties. It expresses a convergence of will between the parties, indicating an intended common line of action. It is often used in cases where parties either do not imply a legal commitme
Metric ton	1,000 kilograms or 2,205 pounds.
MMA	"Ministry of the Environment" (Brazil)
MME	"Ministry of Mines and Energy" (Brazil)
MONSANTO	American private company working on agricultural biotechnology.
Mount Rundle	"Mount Rundle Financial". Company working on investment advisory service, with an emphasis on Brazil and Latim America.
MOU	"Memorandum of understanding".
MT	" Ministry of Transport" (Brazil)
Municipal Solid Wastes	They can be: Biodegradable waste, Recyclable material, Inert waste, Electrical and electronic waste (WEEE), Composite wastes, Hazardous waste, Toxic waste and Medical waste.
N	
N_2O	Nitrous oxide.
NERD	NERD is Non-Esterified Renewable Diesel. There are several varieties of this type of biodiesel, also known as renewable diesel. The most advanced of these is produced through hydrotreating–the same process that is already used in today's petroleum refineries. HRJ is an example of a NERD fuel.
Neste Oil	Finnish oil refining and marketing company producing mainly transportation fuels and other refined petroleum products
NIPE	"Interdisciplinary Center of Energy Planning" from UNICAMP
NGO	"Non Governmental Organization"
Nitrogen oxides	Gases that contribute to ozone formation in the troposphere, where it acts as a greenhouse gas.
Nitrous oxide	A greenhouse gas, emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
NOx	Nitrogen oxides
NWF	"National Wildlife Federation". Non-profit organization working on protecting wildlife and saving habitats.
O	
O_2	Oxygen.
O_3	Ozone.
OEM	An original equipment manufacturer, or OEM, manufactures products or components which are purchased by a purchasing company and retailed under the purchasing company's brand name. OEM refers to the company that originally manufactured the product.

Offtake agreement	An agreement between a producer of a resource and a buyer of a resource to purchase/sell portions of the producer's future production.
Olefins	Any of a class of unsaturated open-chain hydrocarbons such as ethylene, having the general formula CnH_2n.
Oleoplan	Company working on producing vegetable oils, mainly soybean oil.
Oligomerization	A chemical process by which smaller chemical units are polymerized into molecule with a finite, determined number of units.
Ozone	An atmospheric gas. A stratospheric layer of ozone protects the earth from UV radiation. When formed in the troposphere, often through the reaction of oxygen molecules with pollutants such as NO_x, ozone acts as a greenhouse gas.
P	
Particulate matter	The term for a mixture of solid particles and liquid droplets found in the air resulting from fuel combustion. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small, they can only be detected using an electron microscope. PM has health consequences when inhaled and is regulated by the EPA.
PARTNER	"Partnership for Air Transportation Noise and Emissions Reduction".
Partnership for AiR Transportation Noise and Emissions Reduction	A FAA/NASA/Transport Canada-sponsored Center of Excellence that focuses on aviation research, including the development of "breakthrough technological, operational, policy, and workforce advances for the betterment of mobility, economy, national security, and the environment." (PARTNER website)
PETROBRAS	Brazilian oil company.
Petroleum	A generic term applied to oil and oil products in all forms, such as crude oil, lease condensate, unfinished oils, petroleum products, natural gas plant liquids, and non-hydrocarbon compounds blended into finished petroleum products.
Pipeline	A pipe used to transport liquids or gases.
PM	"Particulate matter".
Pró-Álcool	"National Program of Alcohol".
Pyrolysis	Production of bio-oil from biomass by heating at low pressure and high temperature in the absence of oxygen.
P&G	"Procter & Gamble".
Q	
Qualification (of fuel)	Qualification processes are used by specification-writing organizations such as ASTM International to develop new fuel specifications, or to revise existing specifications, to add a new alternative fuel. These qualification processes will include a technical evaluation of the fuel followed by development of the specification requirements and criteria.
R	
Ratoon	a new shoot or sprout springing from the base of a crop plant, esp. sugar cane, after cropping; also a second and successive harvest of sugarcane.
Refinery	A production facility composed of a group of chemical engineering unit processes and unit operations refining certain materials or converting raw material into products of value.
Refining	The process of purification of a substance or a form.

Renewable Energy	Energy generated from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished).
RSB	"Roundtable on Sustainable Biomaterials". An international multi-stakeholder initiative that brings together farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing.
S	
SAC	"Secretary of Civil Aviation" (Brazil)
SAFUG	"Sustainable Aviation Biofuel User Group"
SG Biofuel	An energy crop company developing and delivering high performance bioenergy solutions for the renewable fuel, biomass and chemical markets.
SIF	"Society of Forest Investigation" from UFPR.
SINDICOM	"National Association of Fuels and Lubricants Distributor" (Brazil)
SO_x	Sulfur oxides – an important component of emissions from fuel combustion that can contribute to particulate matter formation and acid rain.
Solazyme	Industrial biotechnology company using standard fermentation facilities to produce renewable oils and bioproducts using microalgae
Solvent liquefaction	Obtaining bio-oil by dissolving solid biomass in a mixture of organic solvents.
SPK	"Synthetic paraffinic kerosene"
Stranded assets	An asset that is worth less on the market than it is on a balance sheet due to the fact that it has become obsolete in advance of complete depreciation.
Supply chain	A system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer.
Sustainable energy	The provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their needs
SWAFEA	"Sustainable Way for Alternative Fuels and Energy for Aviation". An alternative fuel for aviation initiative funded by the European Commission
Syngas	"Synthesis gas".
SYNGENTA	Swedish private company working on biotechnology and genomic research, mainly for seeds and pesticides.
Synthesis gas	A mixture of carbon monoxide, carbon dioxide and hydrogen created by gasification of high carbon-content materials such as coal or biomass. Gasification to form synthesis gas is a part of the Fischer-Tropsch process for producing synthetic hydrocarbons.
Synthetic biology	Synthetic biology refers to both the design and fabrication of biological components and systems that do not already exist in the natural world and the re-design and fabrication of existing biological systems. currently being used by some biofuels companies to convert raw materials into hydrocarbons using biological processes.
Synthetic fuel	Liquid fuel obtained from coal, natural gas, or biomass.
Synthetic jet fuel	Jet fuel made from non-petroleum sources. When this fuel is a "drop-in" fuel, it is also called synthetic paraffinic kerosene. The specifications (ASTM 7566) for synthetic jet fuel for commercial aviation use was passed by the aviation fuels subcommittee of ASTM International, the standards development organization.
Synthetic paraffinic kerosene	Synthetic jet fuel that has similar characteristics to standard petroleum based jet fuel (kerosene). See also "synthetic jet fuel."

T	
Tank farm	A facility for storage of liquid petroleum products or petrochemicals.
TERRABON	American private company working on development and deployment innovative and cost-effective technologies for biomass conversion.
TRB	Transportation Research Board.
Triglycerides	The primary constituent of vegetable oils composed of three fatty acid molecules attached to a single glycerol molecule.
U	
UFL	"Federal University of Lavras" (Brazil)
UFPR	"Federal University of Parana" (Brazil)
UFRGS	"Federal University of Rio Grande do Sul" (Brazil)
UFRJ	"Federal University of Rio de Janeiro" (Brazil)
UFSCAR	"Federal Univesity of São Carlos" (Brazil)
UFV	"Federal University of Lavras" (Brazil)
UHCs	Unburned hydrocarbons.
ULS	Ultra Low Sulfur.
Ultra Low Sulfur	Refers to fuels from which sulfur has been removed to reduce particulate matter from emissions. Its most prevalent application currently is for diesel.
UNESP	"São Paulo State University" (Brazil)
UNICA	"Sugarcane Industry Association" (Brazil)
UNICAMP	"State University of Campinas" (Brazil)
UNIFEI	"Federal University of Itajubá" (Brazil)
UOP	A Honewell Company working on technology development and solutions for the petroleum refining, gas processing, petrochemical production and others manufacturers industries.
Upgrading	Deoxygenation and hydrogenation of conversion products. Normally need expensive catalysts.
Uplift	Amount of fuel drawn from a particular facility for aircraft operations.
USP	"University of São Paulo" (Brazil)
W	
West Texas Intermediate	Also known as Texas Light Sweet, is a type of crude oil used as a benchmark in oil pricing and the underlying commodity of New York Mercantile Exchange's oil futures contracts.
WTI	"West Texas Intermediate".
WWF	"World Wildlife Found". The leading non-profit organization in wildlife conservation and endangered species.
Y	
Yellow Grease	An inedible fat obtained esp. from the parts of hogs not used in making lard, from condemned animals, or from refuse fat.
OTHERS	
1st generation biofuel (1G)	Biofuel made of sugars, starch,r oils or other organic materials, using conventional technology. Examples are ethanol, biodiesel, biogas etc.

2nd generation biofuel (2G)	advanced biofuel made of lignocellulosic, non-food materials. Example: 2G ethanol
3rd generation biofuel (3G)	Biofuel with further processing that turns them undistinguishabel from the petroleum counterparts. Also known as green hydrocarbons. Examples are jet biofuel, algae derived hydrocarbons etc.
4 CDM	“4 Cantos do Mundo” (Brazilian NGO)

ANNEX 1 – REGIONALS OUTREACHES

Victoria Junquera – École Polytechnique Fédérale de Lausanne (EPFL)
Sébastien Haye – École Polytechnique Fédérale de Lausanne (EPFL)
Cristiane Azevedo – 4 Cantos do Mundo (4CDM)
Barbara Bramble – National Wildlife Federation (NWF)

Introduction

By reducing the ambition of the agenda in international climate negotiations, as countries have not committed to national goals for overall Greenhouse Gases (GHG) emissions reductions, the idea of "sectoral targets" gains strength. Some sectors of the economy, regardless of the country, have specific goals to set standards of reducing "carbon intensity" per unit of output.

The aviation industry currently generates about 2% of global anthropogenic greenhouse gas (GHG) emissions. While new aircraft and engine technology, fuel conservation and improved airspace traffic management will help reduce aviation GHG emissions, over the longer term, these advances alone may not be sufficient to offset the projected growth in air travel and emissions. Aviation fuel usage increases at an annual rate of 9% in Brazil. Developing alternative and sustainable sources of this fuel is thus an issue of national significance.

Many the different actors, among governments, as well as the investor community and airlines are committed to providing a low carbon and sustainable fuel that can be used in the current and future fleet, with the certainty that this fuel meets the required specifications, at a reasonable price.

The development of new technologies for sustainable aviation biofuel has the potential to offer the most significant long term contribution to reduce emissions of GHG from aviation. Promising technologies to convert biological materials into jet fuels such as biokerosene have been developed and some have been approved for commercial use.

What does this mean for business in Brazil?

Brazil is recognized as a world power in renewable biofuels. The experience of nearly 40 years in the technology of ethanol from sugar cane, accelerated production of biodiesel extracted from crushing oilseeds (soybean, canola, cottonseed, sunflower), and having a large expanse of available land, give the country a relative comparative advantage to meet this new worldwide demand.

New demands, new consumers and international alliances for the production of biofuel for aviation can provide a great opportunity for sustainable economic development and the associated benefits at the regional and local levels. There may be a variety of potential feedstocks that would be appropriate for this new industry, which can be optimized in different regions of Brazil; this is an additional benefit for the industry, which is interested in having diverse options, because their fuel needs are de-centralized.

Brazil is well known as one of the most naturally diverse countries in the world, with ecosystems that vary from Atlantic Forests, Cerrado and Amazon, with different types of landscapes and climates. With the right policies and research focus, this high biodiversity country could produce a range of regional and sustainable alternative types of biomass for biofuels production.

Biofuel stakeholders and civil society in Brazil are in urgent need to access information about the potential impacts and benefits of the many aspects of the biofuels industry, including jet fuel, and to be recognized as key stakeholders in the process of deciding which are the best options (politically, socially, environmentally and economically) towards a more sustainable development as the industry expands. To better promote an understanding of the challenges and opportunities for the developing Brazilian aviation biofuel sector, 4 Cantos do Mundo and EPFL Energy Center, sponsored by The Boeing Company, delivered three regional outreach workshops, in different parts of Brazil, from September to November 2012, the results of which will be linked with the Sustainable Aviation Biofuels for Brazil roadmap. A separate and more detailed report was prepared for each regional outreach, in Portuguese, which can be available if requested.

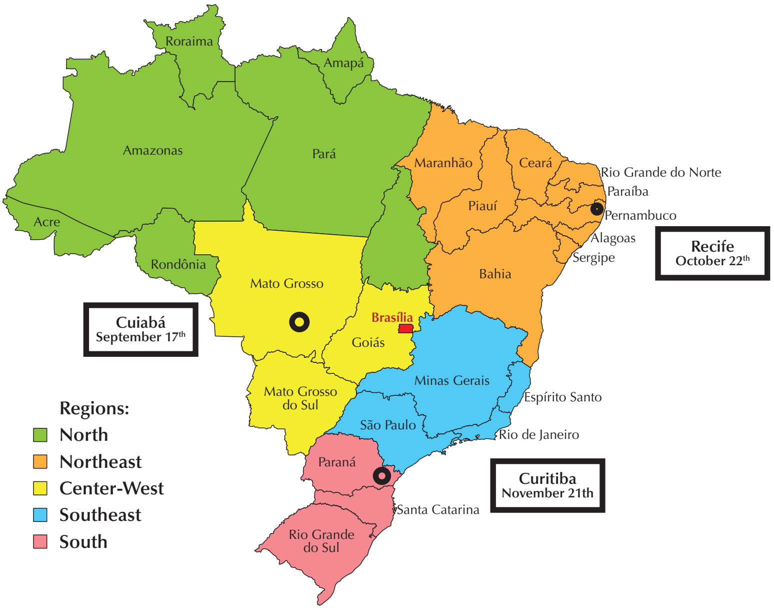

Figure 1 Location and dates of regional outreaches.

Methodology

The one-day workshops had a roundtable format where the participants could feel free to present their concerns and ideas addressing the main themes related to the production of aviation biofuels in Brazil (Feedstocks, Refining technologies, Sustainability, Policies and incentives, Logistics and support, R&D Gaps), but with a regional perspective.

The agenda usually had 4 sessions, two in the morning (Innovation in Biofuels in Brazil and The Challenges of Sustainability and Logistics) and two in the afternoon (Feedstocks for Regional Production of Biofuels and the Challenges for the Industry: Policies and Incentives), allowing time for discussion between presentations.

The participants were local stakeholders, including farmers associations, biofuel producers, NGOs, workers union, academic experts, government agencies, local environmental experts and community organizers, among others.

The main goals were: to discuss with regional stakeholders the challenges and opportunities that the aviation biojet-fuel industry can bring to regional development; understand the challenges related to the implementation of sustainability standards, at the local and regional levels, and provide suggestions on how to best tackle these challenges; knowledge transfer and exchange between different stakeholders on the sustainable production of biofuels, which can use any raw materials and various technological routes for their production; to gather information on the regional potential for a path to sustainable aviation biojet-fuel production in Brazil, and connect these results with the national SABB outreach process, in order provide a full range of recommendations to policy makers.

To facilitate correlating these results with the reports of the national SABB roadmap, the regional outreach findings will be present here divided into separate themes.

Results

1. Feedstocks

As is well known, Brazil has a great variety of feedstocks due to its large production area with good availability of water, different types of micro-climates and multiple regional capacities to promote adaptation of crops.

The feedstocks were the main focus of the regional outreaches, since it's not clear yet which crops will be most promising in the near future for the production of biokerosene; in addition, maintaining a variety of feedstock sources could reduce risks to availability.

The speakers at each outreach session were asked to present their information about which feedstock could create a better interface with both regional development and the demand of the aviation industry; most of them also addressed what is needed to scale up the production of regional crops.

Center-West: The state of Mato Grosso, in the Center-West region of Brazil, is now the largest producer of soybeans in the country – in 2012 alone it produced an estimated 21.4 million tonnes. It is also the first in production of cotton, sunflower and livestock. The state is the 4th largest producer and 2nd largest consumer of biodiesel in the country, producing 206 million liters of biodiesel in the 1st half of 2012.

Although the Center-West region has a lead role in oil seed production, other crops were also presented during the workshop as very interesting alternatives to combine regional development, family farming and biofuels production.

For example, the production of biofuels from a new variety of non-edible sweet potato (*Ipomoea batatas* (L.) Lam.), studied and genetically improved by the University of Tocantins, appears to be a successful option. It can be produced with a proposed "ethanol social seal", and there is already some experience with the whole production chain. It is a rotational crop, which, with simple logistics, can be produced together with other crops such as corn and soy, and therefore scale up the biofuels production capacity of an area. (See BOX – Sweet potato).

BOX – Sweet Potato (*Ipomoea batatas* (L.) Lam.)

This sweet potato is a genetically improved non-edible type, researched for more than 12 years by the Renewable Energy Department of the University of Tocantins.

One project demonstrated a production per hectare of 65 tons, generating up to 10,500 liters of ethanol, more than the 7000 liters generally produced by cane sugar. The starch per hectare is around 24.4.

The processing plant installed in the city of Tangara da Serra/MT in Mato Grosso, handles the production of nine local growers, currently producing 30,000 liters of ethanol per month with standard features and high profitability. Moreover, the plant also includes a parallel bio-diesel facility, which processes cooking oil collected in the city and region by adapted bicycles called "bio-bikes". Each bike carries a volume of 50 liters and each liter of oil produces 1 liter of biodiesel and about 20% of this volume is glycerin.

The processor produces parallel fuel streams, utilizing a "zig zag" system that allows the execution of two processes simultaneously: one for biodiesel and glycerin from the cooking oil, and another for ethanol and animal feed from the sweet potato.

Each ton of sweet potatoes produces 160 liters of ethanol, 150 kg of dry weight of cattle feed, 300 kg of wet waste and 0.8 kg of beta-glucan (used in the pharmaceutical industry).

Furthermore, the wet [and dry] residue produced has 28.5% protein, which is excellent for feeding livestock. This could lead to a densification of the number of head per hectare, reduction of GHG emissions and releasing livestock production areas without reducing yield or causing deforestation.

This variety of sweet potato under study is more resistant to pests and plant diseases than corn and soybeans, is adapted to poor soils and sandy areas (low productivity), has a storage tolerance up to 2 months, it is harvested in 4 to 5 months manually or mechanized, with no need of special machines and can be processed between the harvest seasons of sugar cane, creating a potential extra production of about 90 million liters of ethanol per year.

The production and logistics systems for sweet potato are simple, with low implementation costs; therefore, this production practice could be a viable alternative for family farming to be included in the production of biofuels in different parts of the country.

The Northeast region is currently the area with the highest rate of development in the country. The State of Pernambuco stands out for producing sugar cane, cassava and fresh fruits like banana, grape, coconut, guava and mango. Moreover, it is notorious for the diversity of its raw materials and strategic innovation for regional bioenergy.

One workshop presenter called attention to the production, although not yet on commercial-scale, of biofuels from microalgae. The advantage of microalgae technology is that it does not depend on the supply of crop based raw materials, or costly access to arable land intended for human consumption. The main costs are in labor, and constructing the tanks to serve as bioreactors, fertilizers (urea) and salt (for water salinization of bioreactors). For a hectare of algae production are needed 5000 tons of CO_2, which give rise to 2500 tonnes of seaweed, and half of it is oil. The project described in the workshop is expected to produce approximately 1.67 million liters per hectare / year of algal oils or up to 2.2 million liters of bioethanol per hectare year.

Several palm species were presented as promising such as Macaúba, Licuri, Catolé and Babaçu. All have potential to produce over 5,000 kg per hectare of oil, and the varieties are suitable for conversion to kerosene because of the percentages and characteristics of fatty lauric acids. Many palm species have a very high oil content, and since they are perennial they do not need to be replanted for many years.

Interesting to note is that while some of these palms are already generally grown in all of the Northeast, such as Licuri, others are more specialized (Babaçu only in Maranhão), and Catolé and Macaúba (only thrive in some parts of the Northeast.

Processing would require special attention to the issue of oil extraction, especially with Babaçu, since cracking the coconut is traditionally done manually by women, thus creating many jobs. But it's not clear whether this will remain an economical method of processing, while some local communities still depend on this employment.

It was stressed that the more viable crops in the Northeast would be those that are not irrigated, such as cotton and castor seed. Castor oil has the advantage of possibility to be produced in combination with other food crops (such as maize, for example). Other feedstocks that could be considered include jatropha. Pinhão manso (Jatropha curcas), which has a high oil content, has not been domesticated in the Northeast region yet, and current results demonstrate that further research is needed. So far, the shrubs lose their leaves during the dry season and do not produce oil in quantity, so there are challenges to make it a viable crop in the Northeast.

The oiticica (*Licania rigida*) is endemic to the Caatinga and to the transition zone between the semi-arid of Northeast and the Amazon region. It was presented as an alternative crop because its production is already domesticated and it can also be used to recover river bank areas, thus protecting water resources.

The advantage of oiticica are: environmental (protects rivers in the semiarid region); social (generates income in seed collection), and economic (allows money to circulate in the poorest regions).

A few decades ago, thousands of families depended on the harvest of this fruit to overcome the drought, and this can be repeated if there is encouragement from the authorities. It is a native tree and well adapted to the region, not requiring great care in planting and cultivation. The harvested fruit was exported, for the manufacturing of paints and other industries. Today, there is a market for this raw material, mainly outside the country and possible for biofuels production.

According to the participants, they foresee a transition in the production scenario for sugar cane in the Northeast. Currently sugar cane harvesting is done manually, however due to the overall economic improvement of the country it is becoming increasingly difficult to maintain a workforce for manual production. In addition, the hilly landscape makes mechanization very challenging. This could open an opportunity to invest in other crops in the future, thus enabling the production of biofuels in the Northeast based on oil seeds, such as palm and jatropha.

South: The southern region of Brazil is nationally recognized for its advanced level of social organization, strong governments and highly efficient production capacity. Admittedly a region of great opportunity, a few factors make this a promising region for sustainable investments, such as the quality of infrastructure, development of policies and programs of technological innovation.

The state of Paraná has a variety of local raw materials (feedstocks), with high oil content and which do not compete with food, which could be used for biofuel production. Among them is notable the production of nabo forrageiro, crambe, tungue, cártamo, macaúba and Pinhão Mando (*Jatropha curcas*), which all are studied at the Agronomic Institute of Paraná – IAPAR. Oils derived from such plants have also been studied by the Institute of Technology of Paraná – Tecpar, aimed at producing biofuels.

One of the great opportunities offered by the state is expertise in forest plantations, with now more than 1 million hectares planted, which could be the basis for the production of biofuels for aviation.

Brazil as a whole has knowledge and technology in forestry, especially eucalyptus, planted commercially for 50 years, and now has more than 5 million ha (an increase of 330,000 ha/year). There is a wide availability of land for expansion of the planted area, without competing with agriculture and without promoting deforestation. The knowledge and domain of eucalyptus forestry in the region, with a yield of 40 m^3/ha/year, presents a great opportunity for the use of forest residues to produce biofuels. In addition, forest planting can be used as a cost effective alternative in recovering degraded areas. It is estimated that there are between 50 and 80 million hectares of areas in the country with some degree of degradation, which could benefit from forest planting.

Conclusions: Several agricultural and forest residues could be used in the production of biofuels, including aviation, but one of the main barriers is the need to create effective legislation to regularize the sector.

The main focus should be given to medium sized producers in the near future, since they have more chances to produce at the scale needed for aviation biofuels. Family farming is a good alternative for regional development, but it needs more incentives and it might take a while to scale up to serve this new demand.

It is very important to highlight the agronomic and technological “knowhow” for new and current feedstocks production at the regional level in Brazil. There are several state agronomic institutes such as IPA and IAPAR, local Embrapas, and entities such as CETENE, FAMATO, TECPAR, etc that are working on developing the technology and the knowledge transfer to producers in order to increase the production.

The main challenges presented in these workshops that relate to feedstocks are: i. very few of the regional crops could be produced in large scale in the near future, so further development is needed to scale up production; ii. there is a lack or inefficiency of technical assistance to small and medium producers; iii. in some parts of the country there is a difficulty of harvesting (perhaps developing mini-harvesters would be helpful to support the mechanization of the harvest in areas, especially in the Northeast); iv. there is a need to extend agronomic studies to the new availability of regional raw materials; v. there is need for better education in the form of rural outreach and better access to financing resources; vi. it is important to strengthen cooperatives and other producer associations; vii. there is a need for land use optimization (“vertical” growth productivity); viii. also a necessity to explore further the potential of family farming in the production of biofuels, (more receptivity by the agencies and the fuel buyers); and xi. the meetings emphasized the need to decrease the competition for land between food production and bioenergy.

The main opportunities presented were: i. that there is a potential to increase production of both energy and protein using the same plant, with systems integration (agriculture and livestock) and improvement in the rotation process (e.g. combining soybeans, corn and sweet potatoes); ii. it is important to promote local production to achieve regional development; iii. the search for new raw materials and the research on genetic improvement can lead to lower risks on availability of feedstocks; iv. the creation of a national program for improvement of rural extension can improve the knowledge transfer to producers and increase chances of an integrated production systems; v. Brazil already has a domain expertise in forestry crops and there is a research interest in new sources of raw materials for the production of bioenergy (eg. microalgae and forest residues), which can be better used and supported.

Table 1 Basic Indicators feedstocks presented at the regional outreaches.

FEEDSTOCKS	TIME FOR PRODUCTION	PRODUCTIVITY	BIOFUEL PRODUCED	OIL CONTENT %	VOLUME	PRODUCTION COST (U$/HA)
Sweet potato(1) *Ipomoea batatas*	4-5 months	65 tons/ha	Ethanol	NA	10.500	800
Oiticica(2) *Licania rigida*	NA	75 kg/seeds/ tree	Oil	60 to 63%	2,850 l/ha(5)	NA
Macaúba(3) *Acrocomia intumescens*	4 - 5 years	30 tons/ha (seeds)	Oil	54%	5 tons/ha	NA
Pinhão Manso(3) *Jatropha curcas*	1 year	500 to 1,200 kg/ha (seeds)	Oil	23 to 34 %	1,890 l/ha(5)	NA
Licuri(3) *Syagrus coronata*	6 years	2,000 to 4,000 kg/ha (seeds)	Oil	67%	NA	NA
Catolé(3) *Syagrus cearensis*	5 years	2,000 to 4,000 kg/ha (seeds)	Oil	67%	NA	NA
Castorbean(4) *Ricinus communis*	NA	680 kg/Ha	Oil	45 to 55 %	380 kg/ha	NA
Sunflower(4) *Helianthus annuus*	NA	1,425 kg/Ha	Oil	45 to 55 %	713 kg/ha	NA
Dendê(4) *Elaeis guineensis*	NA	25,000 kg/ha	Oil	20 to 22%	6,000 kg/ha	NA
Cotton(4) Gossypium hirsutum	NA	1,950 kg/ha	Oil	11 to 17%	215 kg/ha	NA
Nabo forrageiro(5) *Raphanus sativus*	NA	1,000 kg/ha (seeds)	Oil	32 to 42%	NA	NA
Canola(5) *Brassica napus*	NA	2,200 kg/ha (seeds)	Oil	40 to 48%	1,190 kg/ha	NA
Crambe(5) *Hochst abyssinica*	NA	1,200 kg/ha (seeds)	Oil	26 to 36%	360 kg/ha	NA
Tungue(5) *Aleurites fordii*	NA	2,000 kg/ha (seeds)	Oil	30 to 35%	650 kg/ha	NA

Table 1 Basic Indicators feedstocks presented at the regional outreaches (continued).

FEEDSTOCKS	TIME FOR PRODUCTION	PRODUCTIVITY	BIOFUEL PRODUCED	OIL CONTENT %	VOLUME	PRODUCTION COST (U$/HA)
Cártamo(5) *Carthamus tinctorius*	NA	1,500 kg/ha (seeds)	Oil	40%	525 kg/ha	NA
Eucalyptus(6) *Eucalyptus spp.*	NA	40 m^3/ha	NA	NA	NA	NA

Sources:
(1) – Presentation Aldo Biodiesel – RO Cuiabá
(2) – Presentation Dr. Júlio Zoe Brito (IPA) – RO Recife
(3) – Presentation James Melo (CETENE) – RO Recife
(4) – Presentation Ivan de Oliveira (IPA) – RO Recife
(5) – Presentation Matheus Azevedo (IAPAR) – RO Curitiba
(6) – Presentation Paulo Eduardo Telles (Embrapa Florestas) – RO Curitiba
NA – Not Available

2. Refining technologies

The refining technologies discussed during the outreach sessions were basically those that have been produced inside the universities and research centers.

The main processes can be summarized in this image presented by Dr. Bill Costa, from Center of Renewable Energy (Tecpar) in Paraná.

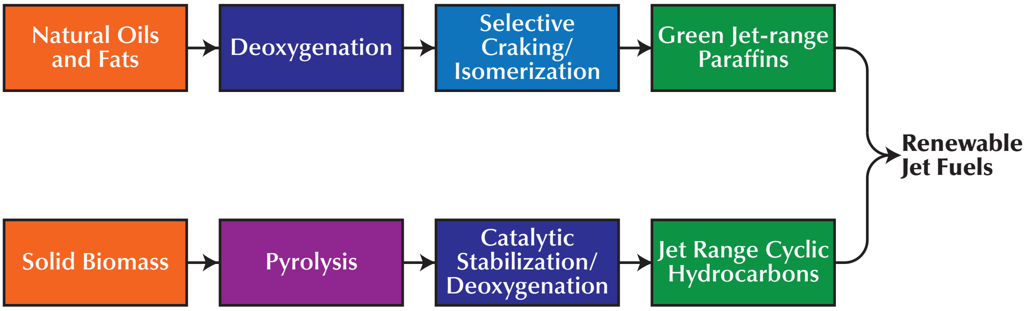

Figure 2 Refining technologies for aviation biofuels.

The main challenges for the regional development of new technology routes addressed by the participants were the lack of cooperation between researchers and industry for research and development of new technologies; the lack of investments for research; difficulty in purchasing equipment for the universities (due to laws and regulations); the need to reduce or mitigate the high cost of innovation projects on a pilot scale and the difficulty of dialogue and high degree of bureaucracy that impedes partnerships between government, industry and research centers.

Other challenges noted were related to the logistics issues, the difficulty of using genetically modified organisms, and the high cost of "scale up" for installations of medium and high complexity such as photobioreactors, in the case of microalgaes.

The main opportunities presented were the interest of regional technological centers and universities in technological innovation, and to improve the dialogue with the industry, and the possibilities of new national and foreigner investments in Brazil to supply these new markets.

A bio-kerosene technology was presented by Adilson Liebsch, from Amyris. They have developed a process to make bio-kerosene by converting sugars into hydrocarbons using yeasts. The sugar is devired from sugar cane, although they state any sugar can be used. This aviation biofuel is expected to be approved by ASTM in 2014. In 2012, Amyris fuel was used in a 50% mixture with traditional jet fuel in an experimental flight of an Embraer Azul Airlines jet during Rio +20. The forecast is for this fuel to be available for commercial use at the World Cup in 2014 in Brazil. According to a study by Icone, Amysis biofuel reduces emissions up to 82% of greenhouse gases compared to fossil fuel.

3. Sustainability

Whether biofuels, and in particular bio-based jet fuels for aviation, can be produced sustainably on a large scale raises important questions, which will affect the long-term prospects for both the aviation and biofuels industries. This subject was addressed in each of the outreach sessions.

As originally formulated at the UN Conference on Environment and Development (the Rio Earth Summit in 1992), the concept of "sustainable development" includes three aspects: social, environmental and economic. It calls for "meeting the needs of the present without compromising the ability of future generations to meet their own needs.". All three aspects are important to both the aviation and biofuels industries.

Economic: From the point of view of economics, a major challenge is how to promote the right incentive policies over time, at regional and national levels, to eventually make the production viable. This requires the right investments, tied to adequate "extension services" (meaning knowledge transfer), and improvement of the capacity of regional research centers to provide information about the best practices of production.

A specific challenge for economic sustainability is that new raw materials (such as jatropha, castor, canola, etc.) are not covered by traditional value chain (it is necessary to understand any business as a supply chain and not just a product). Also, the country produces 59% less biodiesel than it could, which hinders (economic) sustainability. Furthermore there is much uncertainty in planning for production, because it is difficult to forecast the national or external demand for products; as one of the pillars of sustainability, it is necessary to invest in technological innovation and diversification of agricultural raw materials for biofuel production in the country, but outside of traditional crops there is little incentive for this.

Both the biofuels and aviation industries have goals to grow over time, and need public support for that development (in terms of permits for new runways and routes for aviation, and various forms of financial incentives for biofuels). Therefore it makes business sense to avoid controversies, such as conflicts over land, water or labor conditions, food prices and deforestation. In addition, the biofuels industry needs to demonstrate long-term financial viability in a world that may be dominated by climate change and its effects on agriculture.

Social: The main social challenge is to provide more and better employment, without causing major disruptions to rural communities and cultures. Several speakers mentioned the potentially beneficial prospects for regional development when feedstocks and processing facilities can grow at an appropriate scale and pace for local conditions. Agricultural policy should include consideration of community and cultural cohesion as well as enhancements of crop yields.

Environmental: Today, scientists have demonstrated that one of the major threats to environmental security in Brazil, as well as many other countries, stem from agricultural expansion. This has caused deforestation, loss of biodiversity and GHG emissions; risks to water resources from inefficient use of fertilizers and irrigation (increasing both scarcity and contamination); soil erosion, loss of ecosystem services, and other impacts. Since current biofuels production has up till now depended on agriculture, the industry would benefit from being able to demonstrate the ability to expand production while avoiding these consequences.

Also, the production of biofuels may cause additional GHG emissions and water use during processing and refining.

There are many ways to circumvent these potential problems by using best practices in production and processing.

A significant challenge for environmental sustainability in Brazil is the relationship between crop agriculture, forest management and the livestock industry. There currently are 205 million cattle in Brazil, and deforestation is often driven for producing cattle pasture – someone said "Sustainability is the cow" (meaning there is an urgent need to integrate livestock and agricultural crops, and also to avoid deforestation). This integration could lead to a sustainable biofuels industry, because food, feed and fuel could be maximized on the same land.

Opportunities: Presentations were made during the outreach meetings about the potential of global systems of sustainability standards and voluntary certification (using environmental and social criteria), such as the Roundtable on Sustainable Biofuels. This system of certification allows producers to demonstrate to their whole supply chain that they are using good practices. This gives producers an advantage in the market for biofuels, especially aviation fuels, where the buyers are interested in proving the sustainability of their fuel supplies.

Other main opportunities presented were to expand on existing investments in integrated production systems which include livestock and crops, along with soil protection; it would be useful to encourage and disseminate knowledge about these and other best production practices. These would be likely to achieve sustainable certification.

Other opportunities were mentioned, such as to incentivize greater efficiency in production processes (Brazil takes only 35% of potential use of planted forests, for example). And to decrease the historical environmental liabilities, such as avoiding the competition for land between food production and bioenergy, and reducing the use of agrochemicals.

4. Policies and incentives and R&D Gaps

There are an impressive number of laws and regulations related to biofuels production in Brazil and some regional governmental programs are been developed to take their share on this new demand.

At a national level, the actions of the Ministry of Science and Technology promote the production of biofuels and renewable energy, with a focus on biodiesel program and the production of ethanol. For biodiesel, the highlight is the creation of the Brazilian Biodiesel Technology Network (RBTB). In ethanol, the creation of the Center for Science and Technology of Bioethanol (CTBE) and the Network of RD & I for agribusiness development and genetic improvement of sugarcane varieties (RIDESA) have been essential for development. There are many publications made by the Management Centre for Strategic Studies (CGEE) about aviation biofuels, which focus on the progress and technological and economic challenges to the use of this alternative fuel in Brazil and abroad.

President Dilma Rousseff announced recently that will re-create a new national company devote to agricultural extension (EMBRATER), similar to the one which existed in Brazil until the early 90s. This initiative is critical to coordinate national actions of state entities extension. According to the participants, the rural development agents (extension agents) are "the transmission belt of knowledge for farmers," and they are also fundamental to the inclusion of family agriculture. Half of these farmers do not have access to technology, credit and knowledge. Finally, it was emphasized that there is the need to generate income for the producer to stay on the land and also to achieve environmental sustainability.

In Pernambuco, the state government created the program "Todos por Pernambuco" ("All for Pernambuco") with the goal to identify the needs of society and outline a strategy for action.

Through partnerships between government, academia and industries, a vision was developed for the state energy policy until 2014: "Being a state with a technological and industrial base, able to develop, produce and use in excellence solutions to promote clean energy and efficient and responsible use of energy and natural resources". The government did work to identify opportunities in renewable energy: bioenergy, solar energy, SHP (small hydro) and wind power.

In the South, the Paraná State government has adopted a strategic plan for investment opportunities in Paraná, including in the area of technology and innovation.

The plan called "Paraná Competitivo" ("Competitive Paraná") was created in early 2011 to reenter the state into the agenda of national and international investors. The program includes a series of measures, such as the extension of deadlines for payment of taxes (ICMS), and state investments to improve infrastructure, trade, bureaucracy and job training, to make the state attractive to new productive enterprises that generate employment, income, wealth and sustainable development throughout the state.

The benefits are defined for specific outcomes, and take into account criteria such as the type of investment, job creation, economic and environment impacts, and degree of innovation. The more poor and needy is the region, the greater are the incentives granted by the State Government.

Until September 2012, the plan has attracted investments of 20 billion dollars and generated 114,000 jobs. In the area of bioenergy, investments were made for the installation and expansion of biodiesel plants.

In September of 2012, a new law of technological innovation was created, to bring feasibility to the development of new technologies and employment generation in the state. The goals to be achieved by this law are expanding the dialogue between business and academia, increase the accountability and respect for contracts.

The challenges for implementing this law are the lack of specific investments and the difficulty of financing projects.

Some of the challenges reported were the difficulty of dialogue and bureaucracy for partnerships between government, industry and research centers, the lack of skilled labor, the difficulty of articulation between the productive sectors and modernization of public administration to reduce public spending and taxes.

The solutions suggested would be more investment in agricultural research and technology on new materials, the design of better links for cooperation between research institutes, universities and funding, as well as the involvement of industries for technology development and support feasible regional feedstocks.

The strategic actions to overcome the challenges presented include integrated local solutions (potential for regional economic development) and government policies outlining an agriculture-oriented energy, with incentives to produce local raw materials on a large scale. Other key improvements would be to make greater use of the training centers, and increase the knowledge transfer and cooperation among the research centers in the country. The main centers that took part on the regional outreaches were:

INSTITUTION/ REGION	RESEARCH AREAS	WEBSITE
Embrapa Agroenergia/ Northeast	biodiesel; biogas; ethanol; energy forests	www.cnpae.embrapa.br
Embrapa Algodão/ Northeast	cultivars; production systems; biological control; biotechnology; agricultural mechanization; quality of the fibers and cotton; food technology; production of biodiesel from castor	www.cnpa.embrapa.br
IPA – Agricultural Research Center of Pernambuco/ Northeast	biotechnology; natural resources; agroenergy and industrial; crops; horticulture and floriculture; animal production; fruit production; grains, beans, roots and tubers; biocontrol of pests	www.ipa.br
Embrapa Florestas/South	genetic resources and cultivar development; promotion and control of biological agents; ecology of forest plantations; forest management; agroforestry; ecology of natural systems; forest economy; legislation and adding value to wood	www.cnpf.embrapa.br
IAPAR – Agronomic Institute of Paraná/South	chemical waste; bacteriology and virology; plant biotechnology; entomology; plant physiology and biotechnology; herbology; ecological pest managemen; mycology; animal microbiology; nematology; animal parasitology; duck logy seed; soil and plant tissue; animal nutrition; phytopathology; animal reproduction	www.iapar.br
TECPAR – Technology Institute of Paraná/South	analysis and testing technology; biofuels; certification; technological education; extension technology; inspection; artificial intelligence; metrology; immunobiological production; social technologies	www.tecpar.br

Brazil needs a Medium and Long-Term Common Strategic Vision for 2020 – 2050, taking advantage of our potential production chain. It is necessary to create public policies with vision for the future and prospects of investment returns over the long term, to support the expansion of the production of biodiesel with expansion of regional development, social and environmental, allowing the industry to develop projects with goal of achieving greater competitiveness, enhance crop diversification and increase demand.

It is important to seize opportunities, such as the 2014 World Cup and the 2016 Olympics, to promote the country as green fuels leader, and to catalyze policies and processes for the production of sustainable biofuels.

5. Logistics and support

The expansion of investment in infrastructure is a fundamental condition for the acceleration of sustainable development in Brazil. Thus, the country can overcome the bottlenecks in the economy, stimulating increase of productivity and reduction of regional and social inequalities.

The federal government created a program to accelerate the national growth (PAC) through investments in three major points: Logistics Infrastructure, involving the construction and expansion of roads, railways, ports, airports and waterways; Energy Infrastructure, corresponding to the generation and transmission of electricity, production, exploration and transportation of oil, natural gas and renewable fuels, and Social and urban Infrastructure encompassing sanitation, housing, subways, commuter rail, universal Light for All program and water resources. By 2020, the Brazilian transport grid will receive investments of U$ 54 billion.

In the Center-West region, those predicted investments are not real yet. The conditions of the roads are very precarious, most of them have only two ways and very bad signs. The main bottleneck identified was the small investment on roads and rail systems to transport the production out of the state border. The lack of such investments may cause the increase of prices and loss of competitivity of products.

In the Northeast, in the State of Pernambuco, the new investments have a focus on the ports of Suape and Recife (sugar terminal) and Petrolina airport, which are the main exit of sugarcane production and fruit produced in the state. Moreover, there are plans of future investments in logistics infrastructure, focusing on the Transnordestina highway and the Sugar Terminal in Suape.

The Port of Suape is one of the most technological in the country. In 2011, it handled 400,000 containers/year and a possible increase to 1,500,000 in 2014. The access channel is of 390 meters width and 16.5 m deep, allowing big commercial boats to enter. The exports in 2011 were of almost U$ 50 billion. The main export destinations are Russia, Europe, EUA and north of Africa.

The new Transnordestina has a goal of connecting the Port of Pecém (Ceará) to the Port of Suape (Pernambuco), in a total of 1,728 km. It will have the ability to carry around 3 Million/T per year, and has an estimated cost of U$3 billion. The completion date is 2014.

In the South region, the logistics opportunities highlighted were the advantages of strategic location, close to major consumption centers in Latin America (eg São Paulo, Rio de Janeiro and Buenos Aires); logistics for a wide variety of production, with technologically advanced ports (port of Paranaguá); expansion of the rail network, connecting the state from west to east and the creation of mechanisms for integration and cooperation.

The Port of Paranaguá handled in 20 million tons of products in the first half of 2012, which was a total of U$ 8,7 billion. The port has predicted public and private investments of U$ 490 million in the next 3 years.

The state of Paraná had also invested in the railways that cross the border with other states, to connect production areas, such as the connection between Maracaju (MS) to Cascavel (PR) of 420 km.

Conclusion

It was evident from the workshops that Brazil has a huge potential and variability of raw materials to be explored to produce biofuels.

The main challenges were the lack of investment in research and innovation in local and lesser known crops, the difficulty of dialogue among various sectors of society, the complex bureaucracy for access to state resources, the logistical challenge due to the size of our continental country and the lack of training in sustainable practices of producers.

Opportunities and challenges were highlighted in each workshop and this work seems to have planted the seed for more multi sectoral discussions on the issue of sustainability and the importance of planning in land use for biofuel production, agriculture and others. Also the workshops expanded the knowledge of the public about the importance, challenges and opportunities that a new world demand can bring to all stakeholders.

The contacts made and strengthened during the seminars shows once again that the transfer of information, as well as creating opportunities for discussion, are still the best ways to build a participatory process of change towards sustainability.

And with a bit of political participation and multi sector awareness, much can be done to change the course of production and commercialization of biofuels for aviation in Brazil.

ANNEX 2 – STAKEHOLDERS COMMENTS

Andritz Overview

Andritz is one of the largest machine and technology suppliers in the pulp and paper, hydro power, separation, environmental industries.

We have intensified the activities in the pre-treatment and enzymatic hydrolysis area in the last 8 years, and have developed pre-treatment systems for steam-explosion, advanced steam-explosion, auto-hydrolysis, dilute acid hydrolysis, beside our activities in the thermo-chemical area with gasification, biomass boilers, solid-liquid separation, etc.

Commercial Scale Equipment

At the stage in the development of different options to convert biomass into biofuels there are aspects of each process design that require further optimization. However, that is not the case for the equipment associated with these process strategies. The equipment for the material handling, pre-treatment and liquid solids separation operations for lignocellulosic biofuel can be easily transferred from other industries where scale-up to viable commercial plants is well known. Large commercial scale equipment exists in the pulp and paper, fiberboard and chemical industries that can be directly used for lignocellulosic ethanol production. The pulp and paper and fiberboard industries are handling large quantities of biomass every day so there is little risk associated with equipment scale-up. The equipment is already designed and operating at huge commercial production rates in excess of 7,200 dry tons/day of feedstock and can be easily adapted to the lignocellulosic ethanol industry.

The application of this existing equipment to lignocellulosic biofuel such as traditional pulping digesters can be a viable option for bio-reactors for pre-treatment systems, both for dilute acid hydrolysis stages as well enzymatic hydrolysis. Andritz is building small, medium size and very large reactors, along with feeding and washing equipment. Our currently largest reactors are designed for up to 3h retention time and capacities of over 7,500 dry ton/day feed of wood chips.

Similar applies for bio-mass feed systems into reactors, where machines such as plug feeders, impressafiners and rotary valves nowadays mainly used for mechanical or chemical pulping systems are also being used for feeding various biomass feedstock into 2nd generation biofuel pre-treatment systems or thermo-chemical reactors such as gasifiers.

Since many of the 2nd generation biofuel processes require special alloys for a higher corrosion resistance, Andritz is building – and has built units in higher alloys when it is needed (e.g.: duplex, hastelloy or zirconium).

Andritz is already providing the pre-treatment equipment for commercial scale projects worldwide with references for cellulosic ethanol production.

Pre-treatment process development

Our latest delivered pilot plants as well as the commercial systems incorporate an advanced steam-explosion process developed by Andritz. In this concept hemicellulose is extracted at a controlled, elevated temperature, prior to steam-explosion, but while the biomass is continuously kept under pressure. This minimizes the creation of inhibitors otherwise common for single-stage steam-explosion and provides the potential of a separate value stream at the same time. Since this concept is a closed 2-stage process, steam consumption is not higher than conventional pre-treatment.

CAMELINA

Camelina [*Camelina sativa* (L.) Crantz] is an herbaceous annual oilseed plant with short cycle (85 to 100 days from sowing to harvesting) with low watering (rainfall) and fertilizers needs. Its grains contain from 36% to 42% of oil and 27% to 32% of protein. Sowing and harvesting are carried out with conventional farm machinery used on soybean and wheat crops, needing only an appropriate adjustment. The culture of camelina requires no phytosanitary treatment during its cultivation and has some allelopathic characteristics with positive feedback when grown in rotation with cereals and legume.

Trials conducted in Brazil since 2010 by BIOECA Brasil showed that camelina fits in the states of MT, MS, PR and SP as a second crop after the soybean harvest and the sowing deadline date of off-season (“safrinha”) corn. Camelina also fits in the RS, SC and PR as an alternative winter crop. Camelina could fit in the states of MA, PI, TO, BA and GO (must be tested) as a rotation crop, and could also fit in the northeastern states (must be tested), in marginal areas.

These characteristics make the camelina stand out as a non-food crop with low cost and high potential for reducing greenhouse gases (GHG). In addition, camelina fits into a window of opportunity in the agricultural calendar in consolidated areas of agriculture that does not compete with food production, and can rapidly grow your production area.

Native from Europe and Central Asia, from the Brassicaceae family, known and cultivated since the Bronze Age, camelina was rescued from nearly oblivion for nearly 20 years by the high content of Omega-3 fatty acids in your oil. Then began to be cultivated in North America, initially in the USA and then in Canada, in marginal areas where agriculture had not traditionally being done, in the states of Montana, Wyoming and the Dakotas, in the USA, and in the southern provinces of Alberta and Saskatchewan, in Canada.

The crushing of the grains of camelina in a cold pressing produces a meal with a content of residual oil which is used as animal feed, and oil began to be used initially as a feedstock for biodiesel production.

Since 2007, initiatives of civil and military aviation set as its goal the introduction and use of renewable fuels in aviation. Camelina oil has since been the main raw material used for biokerosene production by a process first developed by UOP (a division of Honeywell) of hydrogenation and cracking of vegetable oils and animal fats. This biokerosene was widely tested in turbines and certified by ASTM in mid-2011. This process of producing bio-kerosene is known by the abbreviations HEFA, HRJ or Bio-SPK.

The use of camelina meal as animal feed for poultry and pigs was approved by the FDA in the USA in 2009 and also by the European Commission in June 2011.

Great Plains Oil & Exploration (the Camelina Company), in the USA and Canada, is the world leader in growing camelina, with years of field experience, know- how and own registered varieties. BIOECA in Spain made a joint venture with Camelina Company in 2010 and created Camelina Company España, leader in growing camelina in Europe. BIOECA Brazil became Camelina Company Brazil in late 2013.

GOL Airlines has been supporting the key efforts for the implementation of the Brazilian Biojetfuel Platform, with a special focus on the Plataforma Mineira de Bioquerosene, the Plataforma Pernambucana de Bioquerosene and the Plataforma Gaúcha de Bioquerosene.

Since the historic RIO+20 low carbon flight between Sao Paulo and Rio, as the last leg of ICAO Secretary General's journey into RIO+20, GOL has performed the first commercial flight in Brazil during the Aviator's Day, October 19th, 2013 using HEFA, and has flown 350 low carbon flights with a 4% blend during the 2014 World Cup in Brazil. IDB, Boeing, BR Aviation and partners were supporters of these flights. It is GOL's intention to promote continuous SIP flights in Brazil following the ANP publication of the Resolution 20/2013 with the SIP update.

Since feedstock diversification and sustainable production of biomass are key to a competitive biojetfuel value chain, GOL has also been supporting since 2011 R&D efforts for Jatropha and Macauba in Brazil. Special consideration is being given to the Macauba commercial plantations in Minas Gerais, following a successful domestication program conducted by the Federal University of Vicosa, under the sponsorship of Petrobras.

A Jatropha follow-up program is being reviewed with ABPPM and Embrapa Agroenergia, based on the encouraging results of the Embrapa Jatropha domestication program and concrete advances of JOIL and SGB.

Introductory Camelina trials being addressed by EPAMIG and Camelina Company Brazil.

The use of sustainable soy oil is also being addressed for the Rio Grande project.

LanzaTech

Brazil is a rapidly growing market with strong experience in renewable fuels over a long period, as well as, highly committed aviation and government sectors, making it attractive for research, development and commercialization of sustainable jet fuels.

LanzaTech is revolutionizing the way the world thinks about waste carbon by treating it as an opportunity instead of a liability. LanzaTech's novel gas-to-liquid technology has opened up vast new sources for making low-carbon chemicals and fuels that displace petroleum without the environmental concerns associated with crop- and land-based bioproducts.

LanzaTech's bioprocessing platform offers an economically robust route to carbon capture and re-use enabling the monetization of local gas sources with minimal capital investment, giving off-grid communities access to clean, cost competitive and reliable energy. The patented process uses a biological microbe to convert waste gas containing CO or CO_2 (from industrial sources like steel mills and processing plants) or syngas generated from any biomass resource (e.g. MSW, organic industrial waste, agricultural waste) into fuels and chemicals.

LanzaTech has adopted a rapid commercialization plan that has seen the technology evolve from lab scale gas-to-ethanol technology to a fully sustainable integrative gas to fuels and chemicals platform, proven at scale, that can be deployed globally. LanzaTech, a company founded in New Zealand is now a global organization with headquarters in USA, and facilities in New Zealand, Europe, China, Taiwan and India. Full commercial operation is targeted for 2015.

In 2013, LanzaTech and its partners received RSB sustainability certification for their joint venture's Chinese facility that converts waste steel mill gases to sustainable biofuels. The RSB is a global sustainability standard and certification system for biofuels and biomaterials production. The facility, which uses LanzaTech technology, is the first RSB-certified biofuel plant in China, and the first anywhere to receive this key certification for fuels from industrial carbon capture and utilization.

LanzaTech and Sustainable Aviation Fuel

LanzaTech provides a strategically important route to drop-in hydrocarbon fuels including alcohol to jet fuel (ATJ). Low cost alcohol and 2,3 BDO produced using LanzaTech's technology is converted into jet fuel together with conversion partners. Jet fuel produced from LanzaTech's ethanol has been shown to meet key physical and compositional properties laid out in the ASTM D7566 standard for aviation turbine fuel containing synthesized hydrocarbons. The company is collaborating with aviation industry partners Virgin Atlantic and Boeing along with the ASTM Alcohol to Jet fuel task force to modify the existing aviation turbine fuel standard to include the ATJ pathway.

LanzaTech been awarded a $3 million grant from the U.S. Federal Aviation Administration (FAA) and a $4 million grant from the US Department of Energy to accelerate the development of alcohol-to-jet (ATJ) fuel pathways, with multiple partners including Swedish Biofuels, the Pacific Northwest National Laboratories, and Imperium Aviation Fuels. LanzaTech is working in partnership with Virgin Atlantic to produce the world's first low carbon aviation fuel derived from waste gases.

life technologies™

Few things are certain in life, but one constant remains: a finite supply of fossil fuels cannot sustain the needs of a world population of 7 billion people. The need for biofuels is rapidly evolving at a global scale.

At Life Technologies, we are partnering with the industry's most forward-thinking organizations and employing the most innovative, rigorous, and robust tools on the market to provide comprehensive solutions to the biofuel industry to develop, optimize, and mass produce new, renewable energy sources.

We believe that a key point to improving the development of these new solutions for aviation biofuels in Brazil will be the partnership between excellent research centers, biotech companies, and the companies focused on the production of feedstock, refining or bioconversion processes. These companies will generate the needs, which the research centers will work to address using the state-of-the-art technologies developed by the biotech companies. This collaboration can contribute to speed the processes of plant breeding and modify highly complex pathways to generate optimized host for end products used for aviation biofuel production.

Life Technologies is one of those biotech companies. Life Technologies offers a comprehensive portfolio of Synthetic Biology tools and services designed for metabolic engineering, enabling a more effective approach to optimizing organisms and bio-production pathways, empowering the development of biofuels, energy crops, safe bio-based chemicals, and CO_2 sequestration methods.

MOUNT RUNDLE FINANCIAL

Brasília, Brazil and Calgary, Canada

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Biokerosene Fuel Economics and Financing

The Roadmap For Sustainable Aviation Biofuels For Brazil (SABB) represents an important step in moving towards the development of a viable supply chain for "drop-in" aviation biofuels.

The studies completed and developed through the roadmapping process have demonstrated significant capabilities and viability in a number of areas, including agricultural feedstock development, logistics, transformation and distribution.

It is clear, however, that significant challenges remain to the establishment of a sustainable, financially and economically viable supply chain, primarily due to the relatively high cost to transform raw biofuel feedstock into specification biokerosene. In this regard, fundamental chemistry and energy balances create the challenge to discover economically viable processes relative to the cost of existing conventional fuels.

Supply chain issues are also key in that, at least to start, the establishment of parallel supply chains to handle biofuels will represent additional costs right up to, and in fact through, airport-based fuelling systems. These can, however, likely be addressed by transitional government support policies.

While government policies to insure the full social costs of the use of conventional hydrocarbons will play a role, ultimately the challenge will rest on the ability to develop economically viable transformational technologies. The SABB process created an important inventory of the current options, of which there are many.

This is simply a matter of time and effort, and initiatives such as the SABB process are important steps to support the continuing development of these solutions with a focus on Brazil.

JATROPHA WILL ENABLE BRAZIL TO BECOME A NET EXPORTER OF AVIATION BIOFUELS

Brazil has approximately 200 million hectares of degraded pasture land that can be converted to productive agriculture with innovations and technology. Given that Brazil is a net exporter of food and forestry products, energy crops present a unique opportunity to leverage this enormous area of degraded pasture lands for the production of sustainable bioenergy, including aviation biofuels.

Jatropha is one of the standout energy crops that can grow in the climatic conditions offered by the degraded pasture lands within the Cerrado transition areas of Brazil. Studies conducted by SG Biofuels in Guatemala since 2010 indicate that Jatropha hybrids deliver biomass yields that position the crop as an economic alternative to benchmark ligno-cellulosic and oil-seed bearing species, as well as emerging energy crops that are under domestication.

SGB established Jatropha hybrid trials in 2012 in the states of Mato Grosso do Sul (pictured on the right), Mato Grosso and Minas Gerais in order to demonstrate yield and production cost economics specifically within transitional and degraded pasture lands in Brazil. The trials include evaluations of hundreds of unique hybrid genotypes as well as production agronomy systems. Initial results demonstrate that breeding and innovations in production agronomy systems will deliver the tecnological advances to enable deployment of Jatropha plantations at large commercial scale.

With adequate technology, availability of credit and supporting public policies, it is reasonable to assume Brazilian growers can scale Jatropha plantations ranging from 2 – 10 million hectares within the next 15 years. At this scale, Jatropha will enable Brazil to become a net exporter of aviation biofuels within the next 15 years, a scenario which would generate the following production and sustainability parameters:

Jatropha Annual Production & Emission Reductions Potencial		
Jatropha Planted Area (million ha)	2	10
Jatropha Oil Production (million Mt)	4 – 6	20 – 30
HEFA Jet Fuel Production (million Mt)	3 – 4.5	15 – 23
CO_2 Emission Reduction (million Mt)	8 – 12	40 – 60

Key Assumptions
*** 2 – 3 tons per hectare range of annual Jatropha oil yield**
*** 75% conversion efficiency from feedstock to final fuel product using HEFA production pathway**
*** 75% emissions reductions when using Jatropha based aviation fuel (Bialis, et al. 2013)**
*** 3.5 grams of CO_2 emissions per every gram of fossil Jet Fuel consumed**

solazyme®

About Solazyme, Inc.

Solazyme has pioneered an industrial biotechnology platform that harnesses the prolific oil-producing capability of microalgae. Their technology creates a new paradigm that enables the creation and optimization of novel oil profiles that cannot be achieved through existing oils alone. Solazyme's tailored oils offer enhanced value as compared to conventional oils, and enable Solazyme's customers to enhance their product performance, reduce processing costs and/or enhance a products' sustainability profile. Solazyme's oils are among the most sustainable oils in the world and are drop-in replacements such that they are compatible with existing production, refining, finishing and distribution infrastructure in all of their target markets.

Through standard industrial fermentation equipment, the main production process used to commercially grow Solazyme's algae for oil production, Solazyme can efficiently scale and accelerate microalgae's natural oil production time to merely a few days. By feeding their proprietary oil-producing microalgae plant-sugars in these dark fermentation tanks, Solazyme is utilizing "indirect photosynthesis" opposed to traditional open-pond approaches typically associated with algae growth.

By the end of 2013, Solazyme will commission it's first commercial renewable oil production facility in Brazil with it's joint venture partner, Bunge. This plant will have an annual nameplate capacity of 100,000 metric tons of output oil, or roughly 30 million gallons.

Solazyme's platform is extremely feedstock flexible and can utilize a wide variety of renewable plant-based sugars, such as sugarcane-based sucrose, corn-based dextrose, and sugar from other sustainable biomass sources including cellulosics.

About Solazyme Jet Fuel: Solajet

What is Solajet™ – Solajet™ is the trademarked name for the renewable, end-use aviation fuel refined from Solazyme's proprietary algal oil. It is the world's first microbially-derived jet fuel to meet key industry specifications for use in commercial aviation and is compatible with existing infrastructure.

Fully compliant with specifications — Solajet™ derived from Solazyme's renewable algal oil fully complies with the specification for Synthetic Paraffinic Kerosense from Hydroprocessed Esters and Fatty Acids that specifies bio-based fuels intended to be blended with commercial jet fuel (Jet-A).

Additional Uses – Solazyme's propriety algal oil can additionally be refined to meet a range of other jet fuel specifications (e.g. HRJ-5, HRJ-8).

Benefits – According to the US Navy, Department of Agriculture and Department of Energy Roundtable held on 5/18/12 in Washington, DC, as reported by Biofuels Digest, Solajet's fuel properties when tested in US warplanes exhibited the following benefits while in use: allowed for a faster, farther, greater payload; reduced wing heat stress; made flying at a higher altitude possible; enhanced stealth (low smoke); provided greater pilot reaction time; was a less flammable / safer fuel; was better for the environment; provided a storage life in years vs. months and ultimately lowered maintenance costs.