The development of sustainability requirements for aviation biofuels

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Abstract

Interest in biofuel use is growing in aviation, due to its potential for lower GHG lifecycle emissions and as a possible price competitive alternative to fossil fuels in the long-term (ATAG, 2012). While the use of biofuels in aviation is a new phenomenon, compared to the automotive industry, several actors from the industry and governments have been involved in various initiatives to research, test and use such fuels. Aviation represents a special case, because it can only rely on liquid fuels as an energy source in the mid-term and also because it has not only local but international implications of biofuel governance also. This paper studies using transition theory how the different stakeholders in aviation contribute to the development of sustainability requirements for aviation biofuels and in which areas consensus has been achieved and what future challenges lie ahead. Information has been gathered from relevant literature about how the biofuels are perceived among different entities in the field, which were complimented with expert opinions engaged with aviation biofuels. The literature studied and the opinions gathered indicate the consensus on basic sustainability requirements, however new technologies of biofuels and their impacts are not fully known to stakeholders at this point. It has been indicated that consensus on sustainability requirements would be beneficial at a macro level, but is difficult to achieve due to different government standards and research initiatives occurring at a meso level. Rigorous voluntary biofuel standards are inefficient without government intervention to increase sustainability requirements for biofuels in legislation, while further research is needed to fully assess all impacts of biofuels.

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I would like to thank my supervisor Sara Brogaard for providing her knowledge and advice as well as giving valuable resources to relate my topic to. Her insights and feedback has been a constructive element of my research process.

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Contents

List of abbreviations

ASTM – American Society for Testing and Materials

ATAG – Air Transport Action Group

CO_2 – Carbon dioxide

CTL – Coal-to-liquid

EISA - Energy Independence and Security Act

EPA - US Environmental Protection Agency

EU ETS – European Union Emission Trading Scheme

EU RED – European Union Renewable Energy Directive

EUROCONTROL - European Organization for the Safety of Air Navigation

FAA – Federal Aviation Administration

GHG – Greenhouse gas

GMO - Genetically modified organism

GTL – Gas-to-liquid

IATA - International Air Transport Association

ICAO – International Civil Aviation Organization

IEA – International Energy Agency

ILUC - Indirect land use change

LCA – Life-cycle assessment

NGO – Non-governmental organization

NRDC - Natural Resources Defense Council

RSB – Roundtable on Sustainable Biofuels

SAFUG – Sustainable Aviation Fuel Users Group

US RFS – United States Renewable Fuel Standard (under the Energy Policy Act (EPAct) of 2005)

US RFS2 - United States Renewable Fuel Standard (Under the Energy Independence and Security Act (EISA) of 2007)

USDA – United States Department of Agriculture

WWF - World Wide Fund for Nature

1. Introduction

Since the exploration of crude oil approximately in 4000 BC, it has become a crucial component of our modern economies in the last two centuries (ASTM, 2007). The ease of storage and transportation of this resource has contributed to its widespread use, but most importantly the high energy amount by volume when compared to solid fuels lead to its success (Bessou, 2009). The energy which is stored in this liquid is powering our transportation networks, our industries and nonetheless our electricity generation. With the growing population on our planet, the energy demand will continue to increase in the upcoming decades and expected to rise by 60% in 2030 compared to 2005 levels (Bessou, 2009). The burning of fossils fuels such as crude oil leads to GHG emissions, which are contributing to climate change. The transportation sector consumes 27.6% of the energy used worldwide and is mainly reliant on fossil fuels (Bessou, 2009).

In order to decrease GHG emissions of transportation, other fuel resources can be used such as biofuels among different alternative fuels. This fuel can be easily integrated to existent infrastructures, since the end-products are almost identical to the oil products it can replace. Most importantly biofuels can offer reduced LCA GHG emissions compared to fossil fuels and can also provide local environmental and social benefits if done right (Tilman, 2009). In spite all the benefits biofuels can offer, land conversion and agricultural land use are significant contributors to GHG emissions (Harvey, 2011). The increasing population of our planet means there will be an increase in agricultural activity, which combined with biofuel production must be done sustainably in order to avoid rapid increase in global GHG emissions (Harvey, 2011). While land transportation has alternative resources it can use, aviation will remain reliant on liquid fuels due to technological constraints (Harvey, 2011). This transition in the fuel use of aviation will be presented using transition theory, which will showcase how the stakeholders at different levels of governance engage in the development of sustainability criteria for aviation biofuels.

1.1 The role of biofuels in aviation

Interest in the use of biofuels is growing in aviation, due to its potential for lower GHG lifecycle emissions and as a possible price competitive alternative to fossil fuels in the long-term (ATAG, 2012). This has been a recurring area of interest for the auto industry in the last hundred years and since 2007 the aviation sector is looking at biofuels as a possible way to reduce its impact on the climate (Siegel, 2012; ATAG, 2012). Several organizations in the aviation industry are partnering with fuel producers, processers, aircraft component manufacturers and end-users in order to support research and application of bio jet fuels.

Aviation has determined its targets until 2050, which include carbon neutral growth as well as reduction of emissions by 50% compared to 2005 levels by 2050. These goals are planned to be achieved using biofuels among other measures to curb emissions and cannot be done without them. However present cases show that large scale production can face ethical problems due to competition with food crops, land use change and negative effects on environment and the local population (Buyx, 2011). Learning from the problems such as rising food prices caused by using edible crops for biofuel production in the automotive industry, aviation declines to use food crop based biofuels (Tilman, 2009; ATAG, 2012).

Due to physical traceability challenges, as a result of weak regulations at the moment biofuels used for aviation cannot be followed from the crop to the tank. Also compliance with different regional standards, like the EU RED and the US RFS is difficult for producers, due to different lifecycle GHG requirements by each. Differences among biofuel standards not only impact producers, but also end-users, which are subject to them during international operations and make it less tentative for them to use biofuels if benefits can only be enjoyed in one jurisdiction. US legislation forbids biofuels use by government agencies with higher LCA GHG emissions than fossil fuels, this can be crucial for military use, which as well as civil aviation has shown interest in biofuels. Legal harmonization is required to create global sustainability criteria for aviation biofuels and also regional legislations need to provide volume mandates for such fuels, so they can develop in line with the industry's expectations. (Roetger, 2011)

Despite all the initiatives taken by airlines, the various test flights as well as the few regular flights do not seem to generate the incentive for investment required in the field. The aviation industry needs to send clear signals towards the producers to encourage investment, not only in terms of demand for fuels, but also as common sustainability principles. It has been shown that airlines are willing to use biofuels as a means to cut CO_2 emissions, however the sourcing of the fuels often show the lack of transparency (NRDC, 2013). This in turn could jeopardize the reputation of the industry as a whole. However more thorough sustainability certifications are available than regulatory standards, these are often not applied due to higher costs and the lack of distinction (Sebastien Haye, RSB, personal communication, March 20 2013). This does not mean however that a standard like the one offered by the RSB can cover all aspects of biofuel concerns, as being noted that it can fall short protecting against land grabs (Fortin, 2013). Therefore the widespread use of aviation biofuels are reliant on the consensus of the various stakeholders at different levels about how sustainable biofuels should be defined and also what actions should be taken in order to provide an incentive.

2. Research questions and objectives

The aim of this thesis is to assess how the different stakeholders in aviation engage in the transition towards biofuel use, how the different levels of governance take part in the sustainability criteria development, in what development stage is aviation biofuel at the moment and what forces are encouraging or discouraging the use of these fuels.

Achieving the objective will be done by introducing the existent government standards and voluntary biofuel certifications, which are affecting the biofuel usage in the sector. As of now government standards are applied on all biofuels, not distinguishing the aviation fuel use from others.

The developments of biofuels for aviation users is on-going by the involvement of airlines, producers, governments and other relevant stakeholders, mostly on a country or regional level, defining their sustainability criteria according to their own set of principles, with little or no cooperation among the governing levels. However this industry is using fuels not only within one jurisdiction, but by traveling between continents is subject to multiple legislations. An overall understanding is crucial of the biofuel development within aviation, because the different governing entities need to ensure stringent sustainability principles are adopted and that these are developed by involving all levels of governance in the transition.

Strict sustainability criteria itself is not enough to encourage the spread of aviation biofuel-use, supportive policies need to be implemented in order to encourage suppliers, end-users. Other activities aimed at supplying aviation with non-renewable alternative fuels might pose a risk and need to be discussed to identify its effect on sustainable fuels. A general agreement is required on a macro level how to help actors on lower levels and also to coordinate efforts. Therefore I asked the following questions to accomplish the aim of this research:

1. How is transition towards sustainable aviation biofuels influenced by different levels of governing entities?
    a. What sustainability criteria do aviation biofuels have to fulfill under existing national biofuel standards and voluntary certifications?
    b. How are stakeholder organizations influencing the governance process of aviation biofuels?
    c. What policy options should be considered to enhance and which are limiting sustainable biofuel use in international aviation?

3. Methodology

In the research process I aim to assess how the different stakeholders in aviation engage in the transition towards biofuel use, how the different levels of governance take part in the sustainability criteria development, in what development stage is aviation biofuel at the moment and what forces are encouraging or discouraging the use of these fuels. This will be done through the literature review, which is complemented by the answers of the interviewees. The literature review helps to identify variables which are relevant to the topic and to find inconsistencies and contradictions (Onwuegbuzie, 2012), which might be present when sustainability criteria is being developed for aviation biofuels. I have reviewed and used a variety of sources from reports issued by IEA, USDA, ICAO, IATA, RSB to academic research papers and NGO reports, that represent different opinions to provide a broad overview on the complexity of biofuel in aviation (Onwuegbuzie, 2012). Legitimacy is ensured by using results published by organizations, which are knowledgeable in the field and represent a different interest group (Onwuegbuzie, 2012). Between-source triangulation was used when reviewing the literature, which contributes to the understanding whether there's a convergence of sustainability criteria among the different governing entities (Onwuegbuzie, 2012).

The sustainability principles highlighted in these documents will be compared to the expert opinions obtained by interviewing relevant stakeholders involved in order to identify how and which levels of biofuel governance are influenced by their activities. The two different data gathering techniques formulate a within method triangulation, which is due to that both the literature review and the interviews will be part of a qualitative research (Casey, 2009). The interviewees represent the different entities involved in the creation and implementation of sustainability principles, working with different stakeholder groups. This is being used to provide a comprehensive overview of the sustainability aspects of biofuel development through the data collection (Casey, 2009).

The phone and in-person interviews were conducted in a semi-structured format and on average 45 minutes long and were aimed to establish the involvement of the stakeholders with aviation biofuels and their perception how sustainability should be addressed. In total five interviews were conducted and two participants replied to the questions in a written format. The questions were modified depending on what the stakeholder's share is in the biofuel debate.

Table 1. Interview characteristics

Interview respondent	Organization	Interviewing method	Date
Philippe Novelli	International Civil Aviation Organization	Phone	April 2nd 2013
Sébastien Haye	Roundtable on Sustainable Biofuels	In-person	March 20th 2013
Kati Ihamaki	Finnair	Phone	April 17th 2013
Thomas Roetger	International Air Transport Association	In-person	March 25th 2013
Suzanne Hunt	Carbon War Room	Phone	March 27th 2013
Marcelo Saito	Brazilian agency responsible for the regulation and the safety oversight of civil aviation	E-mail	April 29th 2013

Frederic Eychenne	Airbus	E-mail	June 18th 2013

The involvement of an organization in the biofuel activities of national governments as well as with industry initiatives on an international level was done by interviewing an expert from ICAO. RSB was interviewed as an organization working on biofuel certification. A private company, Finnair was included to compare the preferences and obstacles of the end-users. IATA represents airlines in various discussions related to biofuels and their input was sought to indicate the airlines approach to biofuels. As a non-profit organization supporting market-driven solutions to climate change Carbon War Room was interviewed, as a group providing analyses on various biofuel producers and certifications. The Brazilian agency responsible for the regulation and safety oversight of civilian aviation (ANAC) was also part of the organizations contacted, and has provided valuable information about the government organization and initiatives related to aviation biofuels. Airbus is an aircraft manufacturer conducting business globally, working with local stakeholders on the biofuel value chain developments.

3.1 Theoretical framework

My approach towards the development of sustainability requirements of aviation biofuels will be discussed according to the three conceptual pillars of transition theory, which focus on the phase, level and the nature of change in the transition. Transition theory originates from Jan Rotmans' publication titled: "Societal Innovation: Between Dream and Reality Lies Complexity" (2005). Transitions represent possible development paths, where policy can influence the direction, speed and size of it (Martens, 2005). Transitions can be described as a set of connected changes, which reinforce one another, but originate from different areas, like the economy, technology, institutions, culture, ecology, behavior and belief systems (Rotmans, 2001). Due to the multi-dimensional nature of transitions with different dynamic layers several developments need to occur at the same time across several domains in order for a transition to occur (Rotmans, 2001). Although it is important to note that fundamental changes might not occur in all domains at the same time (Rotmans, 2001). Following the three conceptual pillars I will present the current state of aviation in terms of the phase of transition towards sustainable biofuel use. Based on literature data and interviews I will classify the actors involved according to the multi-levels concept and discuss the interactions between them. Finally I will apply the multi-change concept to highlight where the regulatory framework contributes to the construction or destruction of the transition at the different levels, during the spiral development process. The aforementioned conceptual pillars will be related to relevant literature in sustainability science, which embodies the transitioning of aviation fuel use towards more sustainable alternatives.

3.1.1 Multi-phase concept

According to transition theory, the multi-phase conceptual pillar consists of four different stages in time: predevelopment, take-off, acceleration and stabilization (Rotmans, 2005). The transition itself can be seen as a spiral, which is reinforcing itself (Rotmans, 2001). The following figure illustrates how the different phases are related to time and the state of the system.

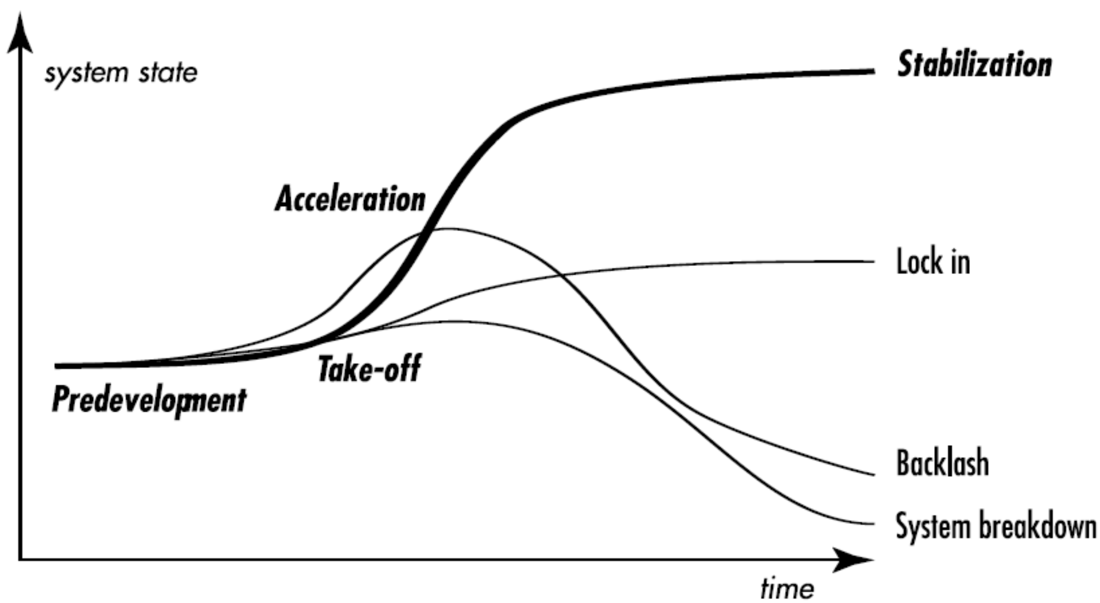

Figure 1. Different phases of a transition and different transition paths (source: Rotmans, 2005)

The predevelopment phase pictures the state of dynamic equilibrium, where the status quo does not visibly change (Rotmans, 2001). In this phase there are negative feedbacks from the regime, which limit the transition to progress to the take-off phase (Rotmans, 2005).

During the take-off phase the state of the system begins to shift due to that the process of change begins (Rotmans, 2001). Whilst the previous phase was dominated by negative feedbacks, this one is subject to the domination of positive ones (Rotmans, 2005). This is characterized by chaos and instability over a short period of time, resulting in an S-shape combined with the acceleration phase (Rotmans, 2005).

Under the acceleration phase visible changes in the structures become temporal and collective learning and diffusion of processes take place (Rotmans, 2001). The acceleration phase is similarly dominated by positive feedbacks, resulting in the aggregate graph to resemble an S-shape (Rotmans, 2005).

Finally the stabilization phase emerges, where a new equilibrium is reached (Rotmans, 2001).

Although the S-curve represents and optimal transition process, other outcomes are possible due to underlying factors, limitations due to decisions in the past, which can result in a lock-in. Reduced diversity due to choices made too early can cause a backlash. An ‘overshoot collapse’ can occur if reverse transition takes place, which leads to system collapse. (Rotmans, 2005)

3.1.2 Multi-level concept

The dynamics of transition are described as interference between three different functional levels, where the three levels are not tied to spatial or geographic scales (Rotmans, 2005). The scale levels represent the functional relationships between actors, structures and processes (Rotmans, 2005). The three levels are the: micro-, meso- and macro-level.

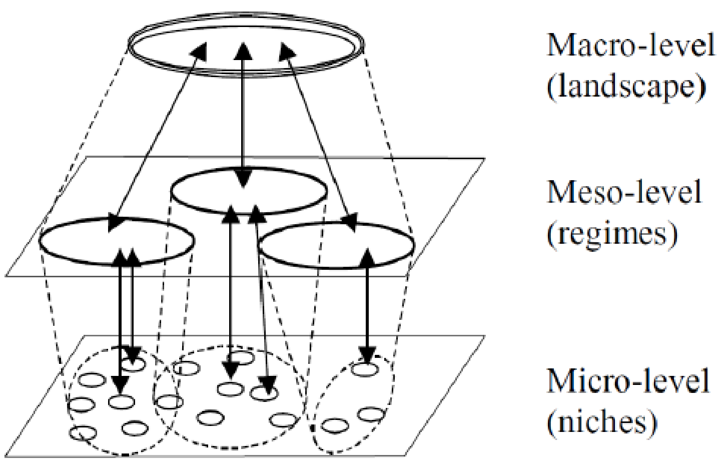

Figure 2. Different levels of transition (source: Geels and Kemp, 2000)

The macro-level covers conglomerates of institutions and organizations, and material and immaterial elements in the socio-technical landscape at a macro-level (Rotmans, 2001). At this level the so-called landscape changes occur, with relatively slow progress and trends development with high autonomy (Rotmans, 2005).

The meso-level encompasses networks, communities and organizations, which relate to dominant practices, rules and shared assumptions (Rotmans, 2001). Existing organizations, institutions and networks at this level create resistance to change and innovation to maintain rules, interests and processes (Rotmans, 2005).

The micro-level consists of individuals or individual actors, where variations to and deviations from the status quo can occur, like new techniques, alternative technologies and social practices (Rotmans, 2001). On this level short-term developments occur, which might lead to rapid success or quick disappearance (Rotmans, 2005).

3.1.3 Multi-change concept

The multi-change concept describes the nature of the dynamics of transitions, that provides a regulatory framework for the relative cyclical process of construction and destruction in transitions (Rotmans, 2005). Due to the intertwined nature of various transitions, they either stimulate or diminish each other (Martens, 2005).

3.2 Transition Theory in the broader context of sustainability science

This section of methodology will be relating the concepts defined by transition theory to the ones found in approaches within sustainability science.

The take-off phase described in the previous section can be related to the concept of multi-change, in which both cases transition is driven by constructive and positive forces leading to the transition of the governance. Understanding complex trends and noting the direction of them is one of the major challenges of sustainability science (Kates, 2003), renewable energies not only need to be originating from a different source than conventional, but also need to produce level of harm per unit consumption (Kates, 2003), which is also crucial for aviation biofuels to succeed on large-scale. Long-term trends and impacts of the biofuel industry are still not fully understood and sustainability standards are constantly developed to accelerate favorable ones and slow the harmful (Kates, 2003).

Transition phases such as the one described as lock-in can be connected to panaceas, which limit the development as a result of simple models based on false assumptions (Ostrom, 2007). Such single type of governance systems are not adequate in order to address the full complexity of aviation biofuels development spread between different functional levels (Ostrom, 2007).

Initiatives like the Roundtable on Sustainable Biofuels have shown the viability of engagement at different levels by entities, which take into account the NGOs, producers and end-users as well as governments and international organizations achieving a consensus on principles. Voluntary biofuel certifications as the RSB Standard fall under the term of co-regulation, which is a combination of public and private regulation (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2013). Under co-regulation states establish sustainability criteria for select sectors and recognize private control mechanisms, which are compliant with the aforementioned criteria (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2013). Such engagement with the public can also create more support for biofuels as well as refining principles by information exchange and intellectual competition with governments. Other organizations are interacting with different stakeholders relevant to their operations, which could tackle the discrepancies of the sustainability debate and help achieve a consensus by the various organizations. This can be seen as part of the on-going trend in governance, where power is shifting from a meso level to a macro level and towards local levels, and also from public to private among the various levels (Kates, 2003). Evidence and experience suggest that there’s a need for including global processes with ecological and social characteristics of micro and meso levels (Kates, 2003).

4. Background: Trends in aviation

The global aviation industry is responsible for transporting 2.6 billion passengers and 48 million tonnes of freight a year, most of this volume is among the developed countries, however it is about to increase in quantity, while also shifting toward developing countries in the future (ATAG, 2012). To transport this amount passengers and freight 260 billion liters of jet fuel were used, which resulted in 649 million tonnes of CO_2 and contributed to 2% of man-kinds global emissions (ATAG, 2012). One of the main reasons why aviation is here to stay, that there are no alternatives to traveling long distances in short time. Therefore considering its emissions it might have a larger contribution to our global emissions if left unaddressed with alternative fuels as biofuels.

4.1 Traffic forecasts

Changes in future traffic volumes will also have an impact on total fuel consumption, despite the annual 1.5% fuel efficiency improvement (ATAG,2012), and it will contribute to the increase of net CO_2 emissions of aviation if biofuels don't succeed. In Europe traffic is expected to increase by 17% by 2019 compared to 2012, this increase will be more significant towards the Eastern part of Europe (Eurocontrol, 2013).

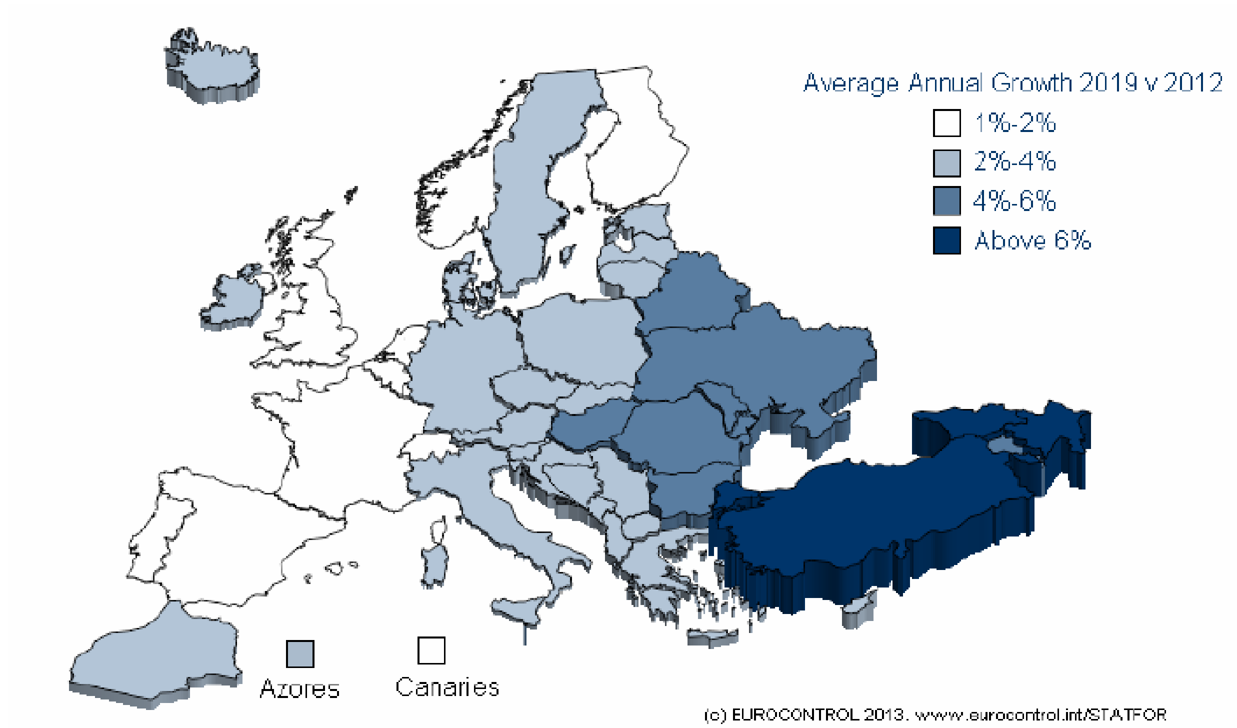

Figure 2. Average Annual Growth of air traffic in Europe from 2012 to 2019 (EUROCONTROL, 2013)

Similarly in the United States' airspace it is forecasted that domestic traffic will grow by 2.3% yearly from 2014 to 2018, which creates more emissions increase what can be resolved solely with efficiency improvements (FAA, 2012).

In contrast other regions in the world also are projected to grow, both in the upcoming five years and also until 2030. The African region is expected to increase annually by 5.1% for passengers, while in the Asia-Pacific region in the same time 6.7% average annual increase can be expected. For the Latin American and Caribbean region an average annual increase of 6.7% is expected, while the Middle Eastern region is expected to grow by 6.6% annually. (ATAG, 2012)

All the forecasts show an increase in traffic volumes, which will in turn cause an increase in aircraft numbers and an overall increase of fuel consumption. IATA claims that from 2020 onwards the aviation industry will achieve carbon-neutral growth, which is based on air traffic management improvements, aircraft efficiency increases and nonetheless biofuels. In order to ensure that biofuels will be a solution for future emissions, they have to follow thorough sustainability requirements, which need to identified and implemented in order to avoid social, environmental or economic failures.

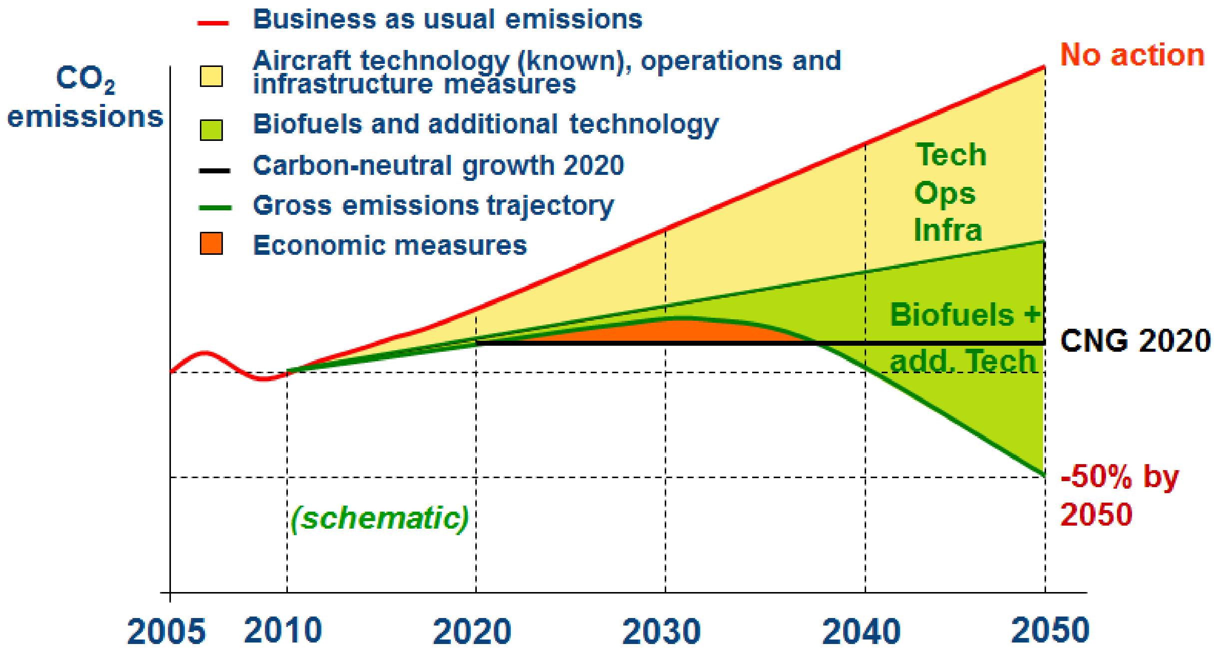

Figure 4. IATA Emission Reduction Roadmap (Roetger, 2012)

4.2 Definitions and facts of biofuel and alternative feedstock types

This section will introduce the basic definitions of biofuels and other alternative fuels, which will aid the reader in the upcoming sections to understand the complex nature of biofuels.

Biofuels are classified in three categories (so called generations) based on the type of feedstock as well as the process used to convert the raw feedstock to a biofuel.

First-generation biofuels can be made from sugar, starch, vegetable oil, or animal fats using conventional technology. Most frequently used first-generation biofuels include vegetable oils, biodiesel, bioalcohols, biogas, solid biofuels, syngas. (Biofuels & the Poor, 2008)

Second-generation biofuels differ from the latter that they are produced from non-food crops, such as cellulosic biofuels and waste biomass. Most frequently used second-generation biofuels include vegetable oils, biodiesel, bioalcohols, biogas, solid biofuels, and syngas. Research in the field is aimed at biofuels including biohydrogen, biomethanol, DMF, Bio-DME, Fischer-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel. (Biofuels & the Poor, 2008)

Third-generation biofuels differ that the oil is extracted from algae. Its production is supposed to be higher-yielding than those of the other two generations. (Biofuels & the Poor, 2008)

Although biofuels offer carbon reductions compared to fossil fuels, alternative fuels which produce more LCA GHG emissions than biofuels are also making their way to the market. Fossil fuel feedstocks as natural gas or coal can be converted with the Fischer-Tropsch process into jet fuel, however in order for these fuels to contribute to GHG reductions, carbon capture and storage needs to be used in the production (SWAFEA, 2013). For the future liquid hydrogen can be a non-CO_2 emitting option in aviation, but storage problems at present would require significant modifications of present aircraft (SWAFEA, 2013).

4.3 Technical standards applicable to aviation biofuels

The ASTM organization creates standards focused on the quality of aviation fuels by testing product performance (ASTM, 2011). In 2011 ASTM, has certified the use of bioderived jetfuels, creating the D7566 International Standard containing the Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons (ASTM, 2011). The specification creates a framework for the use of biofuels processed using the hydroprocessed esters and fatty acids (HEFA) and Fischer-Tropsch methods, while maintaining the safety of air travel (ASTM, 2011). This standard is independent of government standards concerning sustainability and has a different purpose, it defines technical characteristics of the fuel such as viscosity, flash point, sulfur content, freezing point etc. that need to be fulfilled or shall not be exceeded in order to ensure safe operation of aircraft worldwide (ASTM, 2013).

4.4 Government biofuel strategies

Governments have an important role in influencing biofuel development in the long-term, which is mainly done by setting strategic goals to be achieved over time as a proportion of liquid fuels replaced by alternative fuels. Strategies are mainly focused towards automotive biofuels, due to that most of transport fuels are being used in road transport. Aviation biofuels are often included in government strategies as part of liquid fuels without defining separate targets from other transport fuels. This is changing as policymakers are confronted by the growing air traffic is going to have an increasing contribution to mankind's GHG emissions. In this section I will present the biofuel strategies in the three most advanced regions in biofuel use and research, the United States, the European Union and Brazil. These regions were chosen because of their active initiatives and projects which are driving development of aviation biofuels also with the involvement of meso level stakeholders connected to the macro level.

In the United States the Energy Independence and Security Act of 2007 has set the milestones to be achieved by the U.S. RFS2, which mandates the biofuels to be produced in each year (USDA, 2010). The legislation provisions 136 billion liters (USDA, 2010) of biofuels to be produced by 2022 for transportation purposes, this is expected to cover 20% of the total fuel demand (USDA, 2010; Biofuels Digest, 2011). This amount of biofuel production is to be achieved using different types of feedstocks, building on the existent corn-based resources and increasing the amount of advanced biofuels (USDA, 2010). The legislation clearly states the maximum amount of each feedstock type which is supported by tax incentives, limiting corn-based to 57 billion liters (USDA, 2010) and having 79 billion liters (USDA, 2010) from advanced feedstocks by 2022 (USDA, 2010; Congressional Digest, 2008). The biofuels according to the estimates will mostly use land dedicated for feedstock production, while only a fraction of them will come from agricultural, forestry or other residues and expect experimental sources as perennial grasses to succeed (USDA, 2010). At the present moment only gasoline and diesel fuels are under quota requirement, however bio-jet fuels can also receive tax exemption under the legislation, although no quotas are set for production (IATA, 2012).

The European Union by its Renewable Energy Directive has set targets for renewable energy share in transportation to 10% by 2020 (van Dam, 2010). Biofuel use in the transportation sector is expected to increase to 25% by 2030 (van Dam, 2010), which will require 4 to 18% of the total agricultural land available in the EU (European Commission, 2006). Road based freight transport and aviation are expected to increase their fuel consumption significantly by 2030, requiring more kerosene and diesel fuels respectively (European Commission, 2006). The biofuel feedstocks to achieve these targets are estimated to be originating from waste and residual forms as well as from wood and energy crops, both contributing equally in energy content (European Commission, 2006). The EU Biofuels Flightpath Initiative has a goal of ensuring two million tons of sustainable biofuels to be used in the EU by 2020(IATA, 2012). As a private-public initiative its goals are in the short-term to construct three refineries and ensure feedstocks and financial mechanisms are provided to operate them. The long-term goal is full deployment of two million tons of biofuels using nine refineries (IATA, 2012). In addition the European Commission has defined targets to reduce GHG emissions by 60% in the transportation sector by 2050 compared to 1990 levels to limit climate change below 2^0C (European Commission, 2011). For aviation it means use of sustainable fuels will reach 40% by 2050 (European Commission, 2011), along with other emission reducing technologies, such as the modernized air traffic management infrastructure (European Commission, 2011).

Brazil is one of the most advanced countries in biofuel use, which is mainly based on sugarcane-based ethanol. The biofuel mandate for the year 2022 is 50% of the total fuel consumption, which is expected to be 60.8 billion liters (Biofuels Digest, 2011). Rising sugar prices can influence the ethanol content of fuels as it happened in 2011, when the minimum ethanol content was reduced to 18-20% instead of 25% (Biofuels Digest, 2011). The Social Seal is part of the National Biodiesel program, which incentivizes fuel producers to source feedstocks from small-scale farmers (van Dam, 2010). Tax exemptions are given based on a set of criteria, one of them is being the Social Seal, which has created cooperation with 20,000 rural families (van Dam, 2010). The development of aviation biofuels are carried out through international cooperation as well as with local initiatives. In 2011 Brazil and the United States signed a partnership agreement for the development of aviation biofuels with a focus on aviation (Foreign Ministry, 2011). This meant the partnership of such initiatives as Brazilian Alliance for Aviation Biofuels (ABRABA) and the Commercial Aviation Alternative Fuels Initiative (CAAFI) (Foreign Ministry, 2011).

4.5 Biofuel initiatives and operations

Aviation is dependent on drop-in fuels such as biofuels in the short- and mid-term horizon, and therefore the development of sustainable alternative fuels spurred by demand and incentives can contribute to provide sufficient quantities of biofuels (ICAO, 2013). Several research projects and demonstration flights have been conducted by airlines, using various feedstocks around the globe. Such activities create public recognition for biofuels, which bring the attention of media and policymakers to the emissions caused by aviation.

The following map indicates the on-going activities related to aviation alternative fuels, out of which a significant proportion are biofuels. Most of these cover research and development activities, which are crucial for the better understanding of the technological, economic and environmental implications. Several demonstration flight have been carried out by various airlines on different continents to raise public awareness as well as to demonstrate technical viability of biofuels. Despite these activities, policies are still falling behind to support aviation biofuels which are inevitable for the development of sustainable biofuels, not only by supporting the production and use, but also by setting requirements to ensure social, environmental and economic benefits from farm to wings.

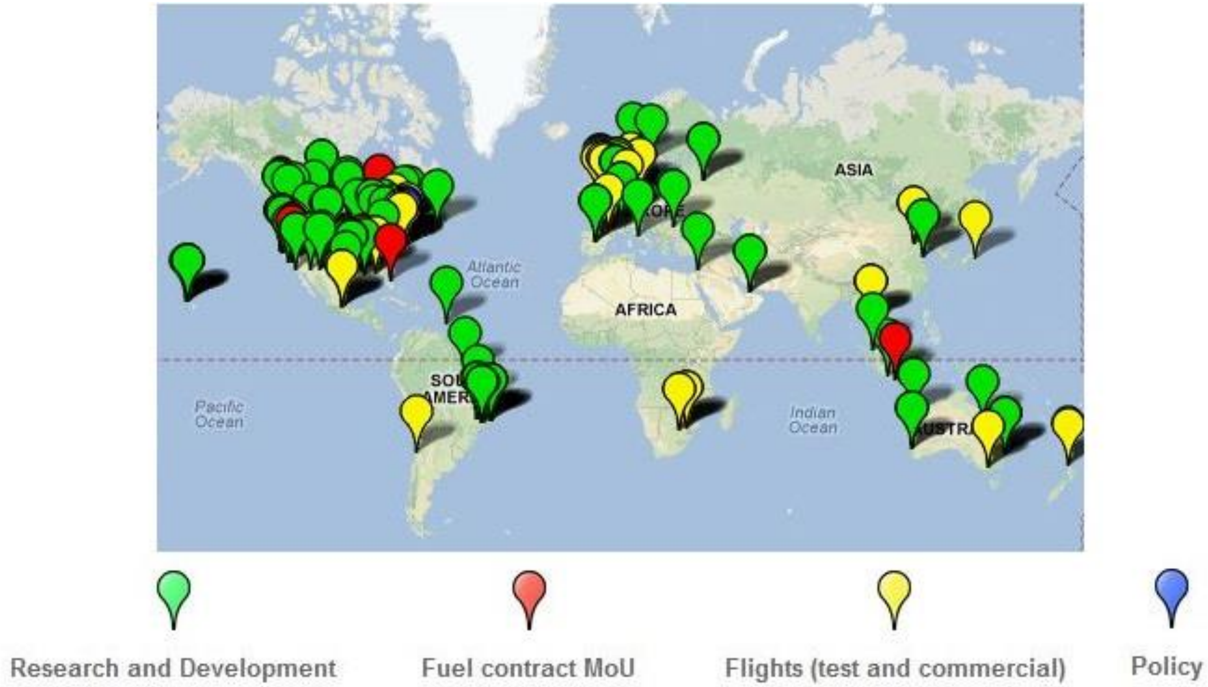

Figure 5. Aviation Alternative Fuel Activities Worldwide Source: ICAO (2013)

In the United States the Commercial Aviation Alternative Fuels Initiative (CAAFI) has been launched in 2006 to promote alternative fuels in aviation. Stakeholders collaborating in CAAFI are U.S. government agencies, airlines, aircraft and engine manufacturers, researchers, energy producers and international participants. 2006 was the first year when due to increasing prices of petroleum made fuel expenses the large component of operating costs for U.S. airlines. The initiative is sponsored by the FAA and three trade associations. For areas are considered during the evaluation of alternative fuels: fuel certification and qualification, research and development, environment, business and economics. (CAAFI, 2013)

The European Union has launched the Sustainable Way for Alternative Fuels and Energy in Aviation (SWAFEA) project in 2009, the main purpose of this study was to assess the possible options and to create a feasible vision and roadmap for deployment. The multidisciplinary approach including sustainability, economics and suitability was done with the involvement of various companies, organizations, research institutes. The project resulted in concluding that there's an actual potential to reduce GHG emissions, a short-term challenge identified the competitiveness of biofuels, while the mid-and long-term issue was identified as the availability and development of biomass production. The policy recommendations included the need for: a sectoral goal for 2020, promotion of "end-to-end" projects, combination of incentive policies, support of research and development and also the harmonization of sustainability criteria was suggested to be helpful. (SWAFEA, 2011)

In 2011 the European Advanced Biofuels Flight Path Initiative was launched by the European Commission, Airbus, European airlines, biofuel producers to support the commercialization of aviation biofuels in Europe. The aim of the project is to reach the yearly production of 2 million tons of sustainable biofuel by 2020. Achieving this is goal is done by creating financial incentives to support the construction of large-scale biofuel production facilities. (European Commission, 2011)

Most recently the Initiative Towards sustAinable Kerosene for Aviation (ITAKA) has been launched by the European Commission in December 2012 to remove barriers to biofuel use in aviation and to contribute to the European Advanced Biofuels Flight Path Initiative. The aim of the project is to produce sustainable bio jet fuel along with testing of it use in existent logistic systems. The feedstocks used are camelina and used cooking oil with a goal of 60% GHG reductions compared to fossil fuel. In order to ensure the sustainability of the fuels the RSB EU RED certification scheme will be used. (European Biofuels Technology Platform, 2013)

The Sustainable Aviation Biofuels for Brazil (SABB) project is aimed at creating a roadmap to implement biofuels in the country, by collaborating with private and public stakeholders. It is a multi-stakeholder initiative to address the challenges of the aviation industry faced due to its small share of the fuel market, competition with other industries and the lack of consensus on a sustainability framework (Sustainable Aviation Biofuels for Brazil, 2013).

The Brazilian Alliance for Aviation Biofuels (ABRABA) was created to promote the public and private initiatives which support the development, certification and commercial production of sustainable biofuels in Brazil. Policy makers and biofuel industry stakeholders collaborate in order to develop biofuels which are equal to fossil fuels in quality, safety and production capacity. (ABRABA, 2011)

The Sustainable Aviation Fuel Users Group (SAFUG) was founded in 2008 by airlines, aircraft manufacturers to focus on the development and commercialization of sustainable aviation biofuels. The members have signed a Sustainable Pledge, which contains the minimum criteria, which needs to be fulfilled by the biofuels. The sustainability criteria defined by the members is consistent with the RSB Standard. It is an alliance, which represents major users of jet fuel, accounting to 32% of commercial aviation fuel consumption. Even though SAFUG members are private actors of the industry, they are committed on collaborating with governments, other industries and representatives of civil society. (SAFUG, 2013)

5. Sustainability criteria under existent government or voluntary standards

Aviation biofuels alike liquid biofuels for land transport are subject to government standards, that ensure that the fuels used are meeting sustainability criteria, which qualify the fuels for tax exemption and/or accounted as zero emission under emission trading. Government standards can be also met by voluntary standards, which can be certified by governments in order to ensure compatibility with sustainability requirements. A producer in order to be eligible to tax exemptions need to comply with government standards, which may have different requirements depending on the feedstock used to produce the fuel. End-users benefit from buying certified fuels by benefiting indirectly from the tax exemption received by the producer, resulting in a cheaper fuel. In this section I will present the government standards that apply to aviation biofuels in the United States, the European Union and Brazil. Afterwards I will summarize the main characteristics of the voluntary standards, which are being used for aviation biofuel certification.

5.1. Government standards applied in different regions to certify bio jet fuel

Government standards for biofuels are created to ensure all biofuels are produced and sourced meeting minimum criteria identified in the legislation. Standards also create equal competition among producers by requiring environmental, social and economic parameters to be met, which in turn does not allow producers to benefit for their own good at the cost of others. Incentives are usually given if the government standard is met, which helps producers to become profitable as well as encourages investment. A government standard can also have quantitative goals, which limit the investment according to national biofuel targets. I will present in the following the United States Renewable Fuel Standard and also the European Union’s Renewable Energy Directive, focusing on the particularities of each standard.

5.1.1. United States Renewable Fuel Standard

The first version of the RFS was created under the 2005 version of the Energy Policy Act, which required starting from 2006 15 billion liters (USDA, 2010) of renewable fuel to be blended into gasoline. This amount was increased up to 28 billion liters (USDA, 2010) by 2012. In 2007 Energy Independence and Security Act (EISA) came into force, requiring the RFS to be expanded to 136 billion liters (USDA, 2010) of renewable fuel by 2022. This new version of the RFS is referred to as RFS2, due to the changes not only in the quantity of the fuel mandate, but also due to feedstock specific environmental requirements. (Congressional Research Service, 2012)

The RFS2 not only defined quantity mandates for the biofuels depending on the feedstock they were originating from, but also required different lifecycle GHG thresholds (Congressional Research Service, 2012). The four categories established under the RFS2 are: conventional biofuels (corn), advanced biofuels (non-corn feedstocks), biomass-based biodiesel, cellulosic biofuels (UN, 2008; Congressional Research Service, 2013). Previously biofuels were usually derived from corn in the U.S., which has created a debate whether food crops should be allowed to be used as fuels, while due to decreasing availability food prices rise (Congressional Research Service, 2012). This lead to the creation of a maximum quantity mandate for corn-based biofuels to be reached in 2015 topping at 56 billion liters (Congressional Research Service, 2012). Also corn-based biofuels only need to achieve 20% LCA GHG reductions compared to fossil fuels, while advanced biofuels like sorghum or sugarcane need to achieve 50% in LCA GHG reduction in order to comply (Congressional Research Service, 2012). The highest life-cycle emission reduction requirements are for agricultural waste product and cellulosic feedstocks, which need to reach 60% (Congressional Research Service, 2012).

Since the aviation industry declines to use food-based biofuels, under the RFS2 it would need to comply with 50-60% GHG reductions, which would increase production costs for aviation biofuel if produced in the U.S. Also if the GHG requirements are not met, the fuel will not be subject to tax exemption. The limitation of food-based biofuels in the RFS2 is beneficial for the aviation industry, due to its commitment towards second generation (advanced) biofuels, which will be more feasible for investors.

5.1.2. European Union Renewable Energy Directive

The Renewable Energy Directive in the European Union has set the goal for the transport sector to achieve 10% renewable sources to be used by 2020 (Ernsting, 2009). This is mainly focused towards land transportation; however the 10% can be met by including aviation biofuels also (Ernsting, 2009). Biofuels under the RED will need to meet at least 35% GHG reductions compared to fossil fuels (Ernsting, 2009), while also biodiversity conservation and good environmental management practices need to be followed (van Dam, 2010). From 2017 onwards, existing production will need to meet 50% GHG reductions, while new installations will need to achieve at least 60% (European Biofuels Technology Platform, 2013). Aviation biofuels which comply with EU RED requirements are also exempt from the European Emission Trading Scheme, which includes aviation activities starting from January 2013 (IATA,2012).

These criteria need to be followed by all member states to meet their targets as of 2020, but it does not prohibit them from setting higher standards than the EU has defined. In addition to previous criteria, in October 2012 the European Commission has proposed changes in current legislation to minimize climate impacts of biofuels (European Biofuels Technology Platform, 2013). The suggested changes were to increase the GHG reduction requirement to 60%, the inclusion of indirect land use change factors in the reporting of fuel suppliers, cap food-crop based biofuels at 5% of current consumption levels by 2020 and to provide incentives for 2nd and 3rd generation biofuels (European Biofuels Technology Platform, 2013).

5.1.3 Brazilian laws applicable to aviation biofuels

In Brazil the National Agency of Petroleum, Natural Gas and Biofuels (ANP) is in charge of aviation biofuel policies and research on a government level (ANP, 2012). The Petroleum Act of 1997 (Lei n° 9.478) implements the national energy policy. In the field of aviation biofuels ANP comply with the following biofuel principles of the national energy policy: use of alternative resources, attraction of investment in energy production, increase competitiveness on the international marketplace, increase of biofuels in the energy mix by taking the three pillars of sustainability into account (ANP, 2012).

Due to the international technical standards, which aviation biofuels need to comply, Brazil has acknowledged the results of the discussions by ASTM, CAAFI as well as the results of the Sustainable Way for Alternative Fuel and Energy in Aviation (SWAFEA) (ANP, 2012). In 2011 the Brazilian government has signed a partnership agreement with the United States for the development of aviation biofuels (ANP, 2012).

Brazil is a major producer of biofuels, however limited information is available on which sustainability standards apply to aviation biofuels or if there are any applicable specifically to bio jet fuel.

5.2 Voluntary standards available for certifying aviation biofuels

Under the EU RED, voluntary sustainability certification schemes can be approved by the European Commission to verify biofuels. These schemes have to meet the criteria defined by the European Commission to be classified as biofuels and to be included in national and EU targets, however they can also have higher requirements than the ones required by EU RED (Ernsting, 2009). In this section I will introduce the voluntary standards, which are accepted under the EU RED and can be also applied on a global level. The following voluntary certifications were chosen based upon, which were already used to certify aviation biofuels or the ones which have been mentioned in the documents by stakeholder organizations and could be applied globally to certify specific feedstocks.

5.2.1. RSB Standard

The Roundtable on Sustainable Biofuels (RSB) is an international multi-stakeholder organization, which collaborates with governments, biofuel producers, suppliers, experts and inter-governmental agencies concerned with the sustainability of biofuel production and processing (RSB, 2013; Van Dam, 2010). It was founded in 2006 in Switzerland by the Energy Center at the École Polytechnique Fédérale de Lausanne (EPFL) (CIFOR, 2011). The RSB Standard is a certified standard under the EU RED, but it can be also applied globally, which is one of the benefits of the multi-stakeholder approach, they have chosen (RSB, 2013). It has 12 principles which are being evaluated when a fuel is certified, these principles help to ensure that the fuel is socially, environmentally and economically sustainable with the inclusion of stakeholders of a biofuel operation. The principles are compliant with the laws, as in the case of the EU RED and also they go beyond the requirements of legislative bodies. The key areas addressed by the principles are: legality, soil, air, water, land rights, conservation, local food security, human and labor rights, greenhouse gas emissions, rural and social development, planning, monitoring and continuous improvement and use of technology, inputs and management of waste (RSB, 2013).

When compared to the requirements of EU RED and US RFS, the RSB standard goes far beyond in land-use impact assessment to origin and sustainability characteristics traceability throughout land rights and invasive species controls as part of their sustainability requirements (IEA, 2012).The certification is applicable to all kinds of feedstocks, regardless whether it is first or second generation. Among the voluntary certification schemes for biofuels, it is considered to be the one with the largest number of social sustainability components (CIFOR, 2011).

In contrast to the benefits of the RSB Standard compared to others, there are concern raised that even though the labor and environmental standards are part of the certification, biofuels will be still produced by profit-driven companies. These corporations will play a role in the on-going expansion of the biofuel production, which might lead to balancing costs to comply with the standard against the external costs. The “Book and Claim” system gives an opportunity for manufacturers to use non-certified feedstocks by requiring them to pay for the market price difference between certified and non-certified feedstocks. This means that even if the end-product is certified by RSB, it not only contains feedstocks which meet the principles. While the standard includes land rights under their principles, it does not disqualify projects, which are under dispute. It has been also voiced that despite the multi-stakeholder approach of the RSB Standard, only a few smallholder organizations take part, which could lead to that private companies have a bigger influence on the principle formulation. (Institute for Food and Development Policy, 2009)

None of the criteria can be failed as a major non-compliance, which covers violations which were not corrected since previous audits. Audits only cover a sample of 5 to 25% of the company's operations, which depends if it is classified as low- or high-risk. It has been noted that RSB certification is not the best tool to solely address indirect impacts, since such macro-level impacts are beyond the control of farmers and producers. (Fortin, 2013)

5.2.2. Bonsucro

The Bonsucro is multi-stakeholder association based in the United Kingdom, which was established in 2005 to reduce the environmental and social impacts of sugarcane production. Much alike the RSB Standard, it can be applied globally to certify feedstocks. It is classified as a standard with lower social sustainability criteria than RSB, but still incorporating some of the criteria. The Bonsucro Standard is also compliant with national laws and international agreements. (CIFOR, 2011)

The Bonsucro Standard has not been applied by the airlines, which have been part of the survey conducted regarding bio jet fuel use by NRDC (NRDC, 2013). In Brazil, where sugarcane is the main feedstock for biofuels it has been already applied to certify feedstocks, while the RSB Standard was not (ICONE, 2012). Since the certification started 17 certificates have been issued in Brazil, in the same year the standard has been accepted as proof of sustainability under the EU RED (ICONE, 2012). The certificates issued by Bonsucro are valid for three years, after the initial certification, annual audits are carried out under the scheme (ICONE, 2012). Bonsucro requires five major requirements to be met for certification: "applicable laws, International Labor Organization labor conventions, minimum wage, impact assessment of sugarcane enterprises on biodiversity and ecosystem services, and greenfield expansion" (ICONE, 2012). From these major requirements all are needed, while from the minor ones, such as those of energy and efficiency, only 80% need to be fulfilled to be approved for certification (Fortin, 2011; ICONE, 2012). The benchmarking of environmental, land use and GHG emissions of the standard against the Brazilian legislation, revealed the lack of criteria by legislation of environmental sustainability requirements, direct land use changes and GHG emissions (ICONE, 2012).

5.2.3. Roundtable on Responsible Soy

The Roundtable on Responsible Soy (RTRS) was established in 2006 in Zurich, it is a multi-stakeholder association covering soybean biofuel certification, which is globally applicable. The main interest of the organization is in Brazil and Argentina, where soy-based biodiesel is being produced. The standard only requires compliance with national and subnational laws. (CIFOR, 2011)

Based on the survey conducted by NRDC, this standard has not been used by any of the airlines surveyed to certify their biofuel operations (CIFOR, 2011). The first farm was certified in 2011 under the standard, while it is used to certify biofuel feedstocks, it can also be applied to soy produced for animal and human consumption (RTRS, 2010). It can be used to certify small-scale producers under Group Certification as well as large-scale producers (RTRS, 2010). It is the only certification scheme besides the ISCC, that has comprehensive procedures and guidelines for group certification (CIFOR, 2011). Crops originating from GMO, conventional and organic production methods can all be certified using the RTRS Standard (RTRS, 2010). The five step certification process includes three audit steps after which the compliance certificate is issued and is valid for five years (RTRS, 2010). It is considered to be in the category of standards, which incorporate some social sustainability criteria (CIFOR, 2011).

5.2.4. Roundtable on Sustainable Palm Oil

The Roundtable on Sustainable Palm Oil (RSPO) was initiated by WWF in 2001, with meetings by organizations interested in 2002 the Organizing Committee was created (RSPO, 2012). Interest in palm oil was growing in the last decade faster than any other vegetable oil due its versatility, high yields and being cheap (RSPO, 2012). Feedstocks are certified along 8 principles, which include: compliance with laws and regulations, commitment towards long-term economic and financial viability, responsible development of new plantations, social responsibility with the parties involved, environmental responsibility, use of best practices (RSPO, 2012). However only 14% of the world's palm oil is certified by RSPO, what mostly includes operations in Malaysia and Indonesia (RSPO, 2012).

The certification became questionable after a failure of handling land-use violations related to a major palm oil producer (Fortin, 2013). Even though the Executive Board found the operation guilty, it has continued to provide certification for the producer (Fortin, 2013). Another example of the roundtable's failure is the certification of United Plantations, which was certified based on its activities in Malaysia, however the Indonesian plantations failed to comply with minimum criteria (Institute for Food and Development Policy, 2009). Opinions are mixed over companies involved in RSPO, some consider it "greenwashing", while others call for the following of sustainability promises made by the companies (Institute for Food and Development Policy, 2009). RSPO applies the "Book and Claim" system along with the "Mass Balance", which allows the end-buyer to purchase certified palm oil mixed with other oil sources (Institute for Food and Development Policy, 2009).

6. Findings

The research questions, which I have formulated in the beginning of this paper and are aimed at how the different stakeholders in aviation engage in the transition towards biofuel use, how the different levels of governance take part in the sustainability criteria development, in what development stage is aviation biofuel at the moment and what forces are encouraging or discouraging the use of these fuels, will be answered in this part by extracting relevant expert's opinion from the interviews. Comprehensive information is available on aviation biofuels and what sustainability principles the different organizations follow when participating in activities, however stakeholder opinions were necessary to introduce areas, which are still under debate or have not yet been discussed widely as part of the transition. The structure of this section will follow the research questions and the relevant sections from literature as well as interview data will be presented accordingly.

6.1 Sustainability criteria applicable to aviation biofuels

As discussed in the previous section, different government sustainability requirements apply to aviation biofuels depending where the producers or end-users would like enjoy benefits of supportive policies. As aviation biofuels are liquid biofuels, they are subject to the same criteria, which are applicable to other liquid biofuels, for example the ones used in road transport. In this section I will introduce the sustainability criteria, which is specifically relevant to aviation under the government standards and also include the stakeholder opinions, which contribute to the understanding of them and the transitioning from fossil fuels.

Under the US RFS2 aviation biofuels are considered advanced due to that the fuel is not based on feedstocks, which can be used to produce food. As an expert has pointed out, advanced biofuels are not only defined by the feedstock used, but also converting any feedstock into jet fuel means it is considered as an advanced biofuel (Suzanne Hunt, Carbon War Room, personal communication, March 27 2013). This means that under present legislation, fuels used by aviation will need to meet 50% GHG LCA reductions, to qualify for RFS2 incentives received by the producers. The EISA excludes products, which originate from virgin agricultural lands that have been cleared or cultivated after December 19, 2007 from what is considered renewable biomass. The EPA has determined that fuels which originate from crop residues, forest material, secondary annual crops, separated food and yard waste and perennial grasses are expected to have less to no indirect land use change effects. (Congressional Research Service, 2013)

Although EPA has GHG targets, which need to be met by biofuels to be eligible to government (meso-level) support, goals for the major parties (meso/micro-level) interested in bio jet fuel use have defined their own goals regarding GHG reductions for bio jet fuels. Airlines for America, which is an industry association representing U.S. airlines require producers to supply fuels which have lower GHG LCA emissions than fossil fuels. Similarly the military requires alternative fuels to be “greener” than fossil ones. (Carter, 2012)

According to Philippe Novelli, the US RFS and the EU RED have different GHG LCA thresholds, why the RFS certified biofuels may not qualify in the EU and vice versa (Philippe

Novelli, ICAO, personal communication, April 2 2013). This also causes problems for producers, whom need to qualify for both systems in order to be able sell fuels on both markets (Philippe Novelli, ICAO, personal communication, April 2 2013). Adding to this, a major problem of present government directives are their uncertainty and the lack of international recognition (Frederic Eychenne, Airbus, personal communication, June 18 2013). This shows how the activities on-going at different levels from macro to micro are connected as part of the transition.

I have asked the stakeholders whether they think fuel such as gas-to-liquid or coal-to-liquid pose a risk to biofuel development. "In the US there's an executive order by the president that government agencies cannot purchase any fuel that has higher GHG implications than conventional oil, so that automatically rules out coal-to-liquid (CTL) for Federal fuel procurement. In theory CTL with CCS could meet the requirement but currently CTL plus CCS is generally cost prohibitive" (Suzanne Hunt, Carbon War Room, personal communication, March 27 2013).

The subsidizing system under the US RFS is done with Renewable Identification Numbers (RIN), which was created to facilitate the compliance with the RFS (USDA, 2011). The RIN is a 38-character code, issued by the U.S. Environmental Protection Agency (EPA) that represents a volume of fuel, which follows the renewable fuel through the distribution system until it is blended (USDA, 2011). The expert from Finnair considers that the "RIN mechanism works very well, but drawback to us, because we don't have a similar, not in Finland, not in the EU… in the US they are getting further and faster because of this system and also in the US there is this military aviation, which is looking at biofuels in such amounts that they also help the commercial airlines develop their policies" (Kati Ihamaki, Finnair, personal communication, April 17 2013)

The EU on the other hand, require aviation biofuels to meet the 35% GHG reduction targets as for other liquid biofuels, which will be increased to 50% starting from 2017 (Ernsting, 2009). A proposal published by the European Commission in October 2012, suggests that ILUC factors should be included in the reporting of fuel suppliers, would require new installations to meet 60% GHG reductions and to provide incentives for fuels with no or low ILUC emissions as 2nd and 3rd generation biofuels (European Biofuel Technology Platform, 2013). In case there's non-compliance with one or more of the criteria, no sanctions are being enforced on member States (Bessou, 2009).

In spite of these improvements on biofuel criteria, “EU legislation is not strict enough on sustainability. The existent criteria are so limited for example there’s no social requirement, nothing on soil, water(except for biomass produced by EU farmers submitted to the cross-compliance rules). By setting bar low of the EU regulations we’re outcompeted by standards with lower requirements. At the end of the day it means less sustainable biofuels entering the market. (Sebastien Haye, RSB, personal communication, March 20 2013)”

In the case of incentives, “EU does not allow member States to set up financial incentives for higher (biofuel) standards. (Sebastien Haye, RSB, personal communication, March 20 2013)” “Harmonization is problematic”, when it comes to different government standards, “… if EU ETS is implemented in aviation, Chinese biofuel has to comply with EU standards” (Philippe Novelli, ICAO, personal communication, April 2 2013). The implementation of the EU ETS on aviation has been delayed so far, due to that it has been deemed as violation of international law and treaty provisions of the Chicago Convention, which was voiced by opponents to the legislation (IEA, 2012).

6.2 Influence of stakeholders on the international governance of aviation biofuels

In the aviation sector stakeholders participate at different levels of governance through organizations related to biofuel market development and research, like SAFUG, CAAFI or ABB. While through these they can make recommendations for policy makers as well as voice a clear demand for supplies by using the market share they represent of the total jet fuel demand. These activities are important for the development of biofuels, stakeholders also engage in dialogues, when they carry out activities related to bio jet fuels within their own organizations and these effects can spread among the organizations paving the way for fundamental changes.

How airlines engage in the use of biofuels and their commitment to sustainability has shown that out of the 22 airlines, which were surveyed for their biofuel operations: none is a member in RSB, none is committed to using Bonsucro, RTRS or RSPO certification and only two are committed to sourcing RSB certified biofuels (NRDC, 2013). Based on these results, it is suggested that airlines make a commitment towards fully certified sustainable biofuels by 2015

(NRDC, 2013). SAFUG, which represents 32% of commercial jet fuel demand, has made statements regarding what criteria biofuels need to meet, but also highlighted that it needs to be consistent with the RSB Standard (SAFUG, 2013). Finnair collaborates with biofuel producers, airports, ministries, NGOs and industry organization throughout their biofuel activities (Kati Ihamaki, Finnair, personal communication, April 17 2013). Industry associations as IATA work with airlines, biofuel producers, suppliers, fossil fuel producers, airports, governments and other authorities regarding bio jet fuels (Thomas Roetger, IATA, personal communication, March 25 2013).

In the case of aviation the commitment from the industry to avoid food based biofuels, is mostly due to "reputational issues as there is much scrutiny over the aviation sector from civil society….other sectors don't have such a sharp choice, because in terms of fuel volume it is 1st generation mostly available" (Sebastien Haye, RSB, personal communication, March 20 2013). Although it is "easy to say a food crop is not sustainable, energy crops are often grown on the same land" (Philippe Novelli, ICAO, personal communication, April 2 2013), adding that "You have good ways to produce 1st generation biofuels and you have bad ways to produce advanced biofuels also" (Sebastien Haye, RSB, personal communication, March 20 2013). The limited land availability also creates boundaries for the amount of 1st generation fuels that could be produced, therefore innovation is required in such as algae creating a solution by combining local production of these resources (Frederic Eychenne, Airbus, personal communication, June 18 2013). In the interviews with IATA, RSB, ICAO experts have indicated that GMO feedstocks are not widely discussed and if yes, approached as applicable if clear overall environmental and social benefits are indicated.

Waste based fuels is an area where most interviewees agreed that they are potentially feasible, however "you have to see what is the best use of that resource" (Suzanne Hunt, Carbon War Room, personal communication, March 27 2013). The type of waste materials, which can be used for fuel production range from non-renewable, fossil fuel based ones (e.g. plastic), to organic wastes. These need further research to determine whether LCA among other criteria as location, show possibility of using such as low carbon transport fuel sources (Suzanne Hunt, Carbon War Room, personal communication, March 27 2013).

The biofuels made from waste are counted as double to the 10% target of renewables, which could incentivize production of more expensive fuels (Ernsting, 2009). It is also perceived as a cheaper source of raw material, however collection and conversion costs could be problematic, leaving room for opportunities in this field (Frederic Eychenne, Airbus, personal communication, June 18 2013).

6.3 Policy options to enhance sustainable biofuel use in international aviation

For the industry to achieve its long-term goals, it requires supportive policies to bridge the price difference between fossil fuels and biofuels as well as to allow advanced biofuels to become cost-competitive. This is partly because "advanced biofuels are still in R&D stage, which means airlines have to pay more for bio jet fuels than fossil-based jet fuels. Most companies claim that in the long run, they are willing to pay the same price due to short margins." (Sebastien Haye, RSB, personal communication, March 20, 2013). Biofuel prices currently are around three times higher than those of conventional kerosene (ATAG, 2012). This indicates the demand for more coordinate efforts in order for aviation biofuels to succeed and achieve a high level of sustainability, which needs the reinforcement of encouraging forces at different levels of governance in order for the transition to proceed to the next phases in the development.

Government policies in particular "can be very helpful for enabling the transition to renewable energy, but the first thing governments should do is to phase out fossil fuel subsidies." "Government purchasing is a very powerful tool. It can be very helpful for the governments to use their purchasing power strategically" (Suzanne Hunt, Carbon War Room, personal communication, March 27, 2013). In terms of increasing the quantity of fuels, "mandates are certainly effective, but you have to have sustainability requirements tied to them to ensure that you don't cause unintended negative consequences" (Suzanne Hunt, Carbon War Room, personal communication, March 27, 2013).As it has been voiced previously by another expert, low sustainability requirements don't encourage the development of truly sustainable biofuels.

Finnair sees that lower landing fees, taxation benefits for using biofuels can be a good supportive policy, but the industry needs to develop these models. While from a government side, using EU

ETS revenues to support biofuel development should be done (Kati Ihamaki, Finnair, personal communication, April 17, 2013).

IATA has expressed the need for incentives for production and use by beneficial tax treatment and de-risking of investments made in the field. This would help ensure the start of large scale production. Blend volume mandates would help producers to fulfill a constant demand and thus encourage investment decisions, but on the other hand bear the risk of jet fuel price increase, which cannot be compensated by tax rebates because of international aviation's tax exemption. Therefore blend mandates are not the preferred choice as long as biojet fuel is more expensive than conventional jet fuel. (Thomas Roetger, IATA, personal communication, March 25, 2013)

The aforementioned policies would be more effective if an international consensus can be achieved on sustainable biofuels, but this is hard to reach. One of the main reasons being that the deployment of aviation biofuels happened without a consensus. (Philippe Novelli, ICAO, personal communication, April 2, 2013)

To increase the sustainability of the fuels, better logistic traceability is required, along with full understanding of indirect impacts(Sebastien Haye, RSB, personal communication, March 20, 2013). Knowledge regarding the GHG emissions over the different processes along the supply chain is also important from a sustainability point of view (Sebastien Haye, RSB, personal communication, March 20, 2013). Finnair sees the possibility of increasing sustainability by harmonizing standards, having a common goal, strategy as an industry (Kati Ihamaki, Finnair, personal communication, April 17, 2013). The lack of harmonization has also been voiced by SABB, that is considered to be helpful to evaluate production technologies and to encourage development of fuel with lower GHG emissions than fossil fuels (SABB, 2013). To achieve higher sustainability of bio jet fuels, stakeholders as RSB, EU & US legislators, research institutes and universities need to actively engage in this field (Kati Ihamaki, Finnair, personal communication, April 17, 2013; Sebastien Haye, RSB, personal communication, March 20, 2013).

7. Analysis

In this section I will analyze my findings according to the theoretical framework, using the three conceptual pillars of transition theory. The conceptual pillars will help gain understanding of the most pressing issues of sustainable aviation biofuels. The theory will also explain the present phase of aviation biofuels, highlighting the possible development paths lying ahead. Using the multi-level concept the interview responses will be categorized according to their position between the three levels, which will explain the contribution of stakeholders at different levels. Finally the multi-change concept will create an understanding of the constructive and destructive forces related to aviation biofuel development.

7.1 Sustainability requirement development of aviation biofuels from a multi-phase perspective

Aviation biofuel use has been developing in recent years, during which it has overcome the initial barriers faced in the predevelopment phase. Since 2007, technical standards have been accepted for biofuel certification, several test flights have been conducted using biofuels from various feedstocks and different types of airplanes. Stakeholders have identified barriers to development, which slowed down the transition towards the take-off phase. High production costs and the sustainability implications of biofuels contributed to the extensive research in technological, economic and environment aspects.

Environmental impacts of biofuel production are often simplified to LCA GHG reductions, while other issues are only touched upon. All government standards discussed require a certain level of LCA GHG reductions for biofuels to be qualified for benefits. The main reason being that aviation's interest in biofuels is to reduce the GHG impacts of their operations and achieve carbon neutral growth in the future. Second to this are the feedstock issues, which are shared with other users of biofuels, aiming not to compete with food crops, but aviation has made a firm commitment to avoid using such crops. The question of which crop to use does not resolve the problem, due to indirect land use changes, which shift the debate towards the land being used rather than the crop grown.

Experts were asked whether considering food crops as a feedstock would benefit aviation and even though rejection from certain stakeholders, there are countries like Brazil which has decades of experience successfully using sugarcane as a fuel source. It has been mentioned in terms of supply that most of the capacity is available in first-generation feedstocks. Another reason why considering food crops can be viable is that yields are more stable of food crops (which have been domesticated for decades), than those crops which have been only cultivated due to interest in biofuels (Loran, Spaeth & Teixeira, 2013). Until research has proven that advanced feedstocks under development are capable of providing yields financially feasible, certified first generation feedstocks could be a solution to ensure sufficient fuel supply. This shall be only done with the complete assessment of indirect impacts and application of certifications with high sustainability requirements. Higher government standards for food crop based biofuels could ensure that no negligence occurs in such operations.

Out of the three pillars of sustainability, the economic aspect of aviation biofuels is a major barrier to move from test-flights to large-scale deployment (Roetger, 2012). This “valley of death” which needs to bridged, which is between the price of conventional fossil fuels and aviation biofuels (Roetger, 2012). The economics, which influence biofuel development are closely tied with government policies, which can support market expansion as well as ensure high sustainability criteria are being applied in the whole supply chain of biofuel production.

Airlines conduct tests and regular flights more often using biofuels, often using the airline’s own sustainability criteria. However not all of the fuels are being certified by well-known standards. As the survey by NRDC has shown, not all airlines are willing to disclose their sustainability requirements, leading to speculation over their credibility. The use of voluntary certification schemes can provide transparency, which could be required in order to benefit tax reliefs granted by governments around the world.

All governments, interested in aviation biofuel use, have established initiatives, which with the collaboration of airlines, aircraft manufacturers, biofuel producers, etc. to research and develop the processes required to scale up production. Collaboration among these initiatives has already begun, but this has to continue in order to bridge the gaps in knowledge about specific crops, logistic processes.

Based on the findings of the interviews and the relevant literature, it can be concluded that aviation biofuels have successfully proceeded to take the next step and are progressing into the take-off phase. Projects like the ITAKA are aiming at supporting commercial scale projects, which reach beyond previous experimental efforts. Also the wider availability of feedstocks that can be used gives flexibility for producers to meet the fuel demand of the aviation industry. This, however, is not a guarantee that the acceleration phase will be achieved, unless the concerns over costs and environmental implications are resolved. It further reinforces the need for a joint effort to standardize sustainability requirements at an international level.

7.2 Application of multi-level concept

Transition towards sustainable aviation biofuels can be structured how stakeholders interact on and among different functional levels. The three levels, macro, meso and micro will be discussed separately to structure the challenges and goals of stakeholders and how they interact with other levels. Interviewees' opinions will be connected to literature relevant to the level their organization represents itself in the transition process and vice versa.

7.2.1 Micro-level

The individual actors which were part of the research during interviews are representatives of Finnair and Carbon War Room. These actors are subject to short-term changes in the field, which could lead the success of biofuel use, while failure could be the result due to the high exposure to economic and environmental factors.

End-users are subject to economic feasibility at a micro level, which needs to show positive implications in order for the actors to incorporate biofuels in their operations. The "valley of death" at present is the most significant barrier, which represents the price difference between fossil and biofuels, the latter being significantly more expensive (Roetger, 2012). However it can be concluded that in the long-run biofuels are expected to be cheaper than fossil fuels, reducing operating costs of airlines.

Government incentives can positively impact market development, by encouraging producers to produce certain types of biofuel using a variety of feedstocks. The feedstock categories have determined the volume mandates in the US, which signal to the producers what amount of each fuel type is subject to tax incentives using the RIN system to measure progress in each. The fuels are classified into four categories, each with its own GHG reduction requirements, which need to be met in order to be accepted under the RFS. But government legislations not only have to ensure quantity, but also quality, which can be achieved by government established standards that are either enforced by the legal authorities or by voluntary schemes, that are accepted by the government. These voluntary certifications need to comply with the government regulations, to ensure eligibility for benefits to the producers. However, on top of the official sustainability requirements producers can choose whether to exceed those or not.

The different types of new biofuel feedstock sources not only show environmental potential, but also can impact the end-product's price, which is impacting preferences of end-users. Waste-based biofuels need to be considered, depending on their potential and shall be evaluated whether it is environmentally feasible to use them as fuels. Finnair would prefer locally sourced fuels, which is subject to feedstock availability. Rapid changes in this field can be expected as a result of better technological and environmental understanding of the new feedstocks.

7.2.2 Meso-level

The meso-level encompasses networks, communities and organizations, which relate to dominant practices, rules and shared assumptions (Rotmans, 2001). In the spread of aviation biofuel use government organizations, initiatives along with international biofuel certifications have a major involvement how dominant practices are developed and which rules are applicable to aviation biofuels. The extensive literature review covers activities in all three study areas, which can be related to government actions and policies. These are supported by responses received from ANAC, RSB and Airbus.

While government standards cover only certain parts of biofuel sustainability, mostly focusing on environmental requirements and economic issues, social standards are delegated to voluntary schemes. During the introduction of the voluntary schemes, it was obvious that even though they aim to cover many of the social aspects, such as land rights, labor rights, gender aspects, all had opinions voiced against about the enforcement of those. Due to that biofuel production includes many actors during the supply chain in various geographical locations, certifications need to include all to ensure sustainability is being met throughout the value chain. Bridging the problem of certifications having different major and minor criteria and also different compliance requirements with these should be addressed by initiating talks by governments about the topic, possibly delegating to the macro-level. As it was mentioned in the findings, government requirements leave room for lower standards, which only cover the requirements defined by law and lack to go beyond. If governments would agree on an international level, what minimum criteria should be met for biofuels, it would eliminate operations and certifications schemes, which risk the reputation of liquid biofuels.

More comprehensive government standards are needed, which can be expanded to cover all operations related to biofuels. In the case of indirect impacts, which are affecting livelihoods of people in developing countries, the sooner they will be covered, the less negative reputation will be caused due to negligence of producers.

Governments can not only provide incentives for production of biofuels, but they can encourage investment in processing facilities. Investors are reluctant to invest in aviation biofuels, due to unknown future demands by the industry. De-risking investments can be done by government loans, which would reduce the financial risk, thereof resulting in more capacity for bio jet fuels production. Many airlines are owned partially by governments, which could lead to buying agreements with producers to encourage production. Similarly, the US military and other armed forces could make similar contributions and commitment toward the use of renewable energies and bio jet fuels in particular (Carter, 2012).

At present each jurisdiction has developed its own biofuel standard, which provides incentives for producers if criteria are met. However this makes it expensive and complicated for suppliers to export to multiple markets, which have different requirements and certification processes. Mutual recognition at an international level would benefit not only producers, but also end-users by having a more flexible supply chain, which can adapt to changes in demand. Present problems at the meso-level can be resolved by consensus at a macro-level, however it would mean slower advancement in regulation.

7.2.3 Macro-level

The macro-level covers conglomerates of institutions and organizations, and material and immaterial elements in the socio-technical landscape (Rotmans, 2001). At this level the so-called landscape changes occur, with relatively slow progress and trends development with high autonomy (Rotmans, 2005). The interview results from representatives of ICAO and IATA have contributed to the understanding of aviation biofuel development challenges in relation to sustainability, which are present at an international level. While the macro level consists of supra-governmental organizations, also international initiatives as SAFUG, which represent members from various industry companies on multiple continents are included in the macro-level.

Long-term viability of aviation biofuel use is not only dependent on environmental and economic criteria, but also social aspects of these renewable feedstocks along with indirect impact need to be addressed. The growing demand for aviation biofuels is inducing development of them due to the issues caused by deployment from a sustainability point of view, encompassing social aspects. While regulatory standards cover some of the social implications, more thorough requirements are offered by voluntary certifications. (IEA, 2012)

Strict government regulations do not resolve problems voiced over the social aspect of voluntary certifications, enforcement needs to be set up to penalize those companies which do not comply with the requirements. Audits have an important role in assessing operations, which need to cover the whole supply chain and especially all production areas, so there are no mixed practices between exploitative and sustainable feedstock production.

As an interviewee mentioned, incentives for higher voluntary standards are forbidden in the EU, which could benefit airlines by distinguishing themselves from other industries. In order to aid higher voluntary certifications to be used by producers, a ranking would be necessary, which rank the schemes and impose progressive incentives the higher they rank among the others.

Renewable Jet Fuels provide rankings of biofuel producers, one aspect is sustainability, which contribute to the overall ranking (Renewable Jet Fuels, 2013). Similarly rankings could be created by an independent organization for voluntary certifications, which would help policymakers to define which will be most incentivized.

Expert opinions have revealed that definitions, e.g. depending on which generation the biofuel belongs to, not only are dependent on the feedstock, but also the process which is being used to convert it to fuel. Also there is no clear opinion on genetically modified crops, acceptance is dependent on production potential, which is still under research. Consensus on these issues is necessary to help sound development, without miscommunication among different entities. While each government has different LCA GHG emission reduction requirements, establishment on minimum criteria for feedstock categories at an international level could contribute to meeting environmental goal of the industry at a longer term.

The macro-level issues of aviation biofuels shows that although support provided at government levels help the development, and spur of local use, but is not consistent at an international level, which poses problems to producers as well as environmental credibility. Delegation of government interests at this level could be beneficial in order to create a more consistent and transparent market, while also having a universal sustainability requirements.

7.3 Multi-change pillar of aviation biofuel sustainability requirements

The multi-change concept describes the nature of the dynamics of transitions, that provides a regulatory framework for the relative cyclical process of construction and destruction in transitions (Rotmans, 2005). Due to the intertwined nature of various transitions, they either stimulate or diminish each other (Martens, 2005). Rising oil prices not only support biofuel use, but less sustainable and price competitive alternative fuels also. While GHG requirements for fuels are only applied in some countries, the wider availability of feedstocks which can be used for biofuel production helps the transition towards biofuels from kerosene. In the following section I will present the supportive and opposing dynamics of transitioning towards sustainable biofuel use.

Due to that biofuels are expensive compared to fossil fuels, other alternative fuels are also being considered to replace kerosene. Some of these fuels have higher LCA GHG emissions than conventional fossil fuels, this is due to the energy intensity of the processing as well as that raw materials as coal or natural gas are used to create them. Consensus from the industry on the utilization of such fuels is necessary in order to avoid contradicting practices. If global GHG emissions are expected to rise, without biofuel deployment, alternative fuels with higher LCA GHG emissions than conventional fossil fuels shall be banned.

Waste based fuels is an expanding field in alternative fuels, it can utilize renewable and non-renewable feedstocks. Similarly, operations that result in higher LCA GHG emissions than fossil fuels shall be avoided. Due to the different waste materials, that can be utilized it is important to evaluate what is the best use of the resource. Although waste based fuels have limited feedstock availability, several demonstration flights have utilized biofuels made from used cooking oil.

Resolving the challenges of traceability of biofuels could lead to a better understanding of indirect impacts. Practices as "Book & Claim" by producers under certification schemes not only support feedstock producers with no sustainability criteria, but also make traceability of the fuel more difficult for voluntary schemes. International standard harmonization could aid the better logistic traceability of fuels.

At present each country or region has its own biofuel sustainability requirement, which is incentivizing production if the requirements are met. Although consensus on an international level is more difficult to achieve, but limited feedstock availability might pose risks to end-user due to the limitation of producers to only export to one of the markets. The mutual recognition of legislative standards would benefit not only producers but end-users as feedstock availability will become a pressing issue due to growing demand.

Cooperation at a higher level shall not only be limited to mutual recognition, but in order to achieve sectoral goals, agreement on definitions and practices is needed. GMO based biofuels might have potential in the future, but without clear commitment towards them, neither investment is encouraged, nor environmental disasters can be avoided.

The certification schemes discussed in relation to aviation biofuels have been criticized for the majority of stakeholders representing companies' interests, which might impact how audits and impacts are being assessed. Even though most of the mentioned schemes are roundtable initiatives, which is a good approach to include different stakeholders of biofuel production, use and development of biofuels needs the inclusion of stakeholders not actively involved in the production. Ensuring equal representation of stakeholders in these certification organizations should be in order to avoid issues, which could result in environmental or social problems not relevant to the majority. This could lead to a better understanding of impacts of biofuel operations. Similarly to organizations providing voluntary certifications, industry initiatives for aviation biofuel development and research are often roundtable initiatives, which could benefit from equal representation.

Opinions about first-generation biofuels and their impacts need to be debated upon, due to the conflicting opinions over land use, however as the experts have pointed out, the same problems might occur with non-food based biofuels alike. Genetically modified organisms are primarily present in food production, however there is on-going research related to how genetic engineering could assist biofuel production. While most of the GMO research is focused at land-based crops, algae are being considered as an option to avoid competition for land. Genetic modification can speed up algae growth, which would have a positive impact on the economics of fuel production (Lacey, 2011). Even though companies involved in research consider the algae's created to be non-harmful to the environment, yet there's lack of proof if environmental problems can be avoided (Lacey, 2011).

Constructive forces for sustainable aviation biofuel use are coming from new feedstocks, but lack of consensus about GHG LCA reductions, certification practices, feedstock choices are developing the use of the fuels in different directions, which slows down advancement and also could cause failure of overarching goals.

8. Conclusions

During my research I've found that different stakeholders of aviation biofuel can contribute to certain aspects of the adaptation of more rigorous sustainability standards, however it has been voiced by experts as well as literature, that governments need to make the initial steps towards higher standards. The thoroughness of biofuel sustainability standards are closely tied to market development, which requires incentives in order to thrive as more detailed certifications are more expensive to obtain. Incentives specifically for aviation biofuels can be provided in the forms of tax exemptions and government buying contracts. Even though food crops are not chosen by airlines due to reputational reasons, sustainable practices and large feedstock availability should be considered by end-users until advanced biofuels become more easily accessible. Technologies which have higher LCA GHG emissions should be banned due to that the use of those could jeopardize the overall GHG reduction goal of the civil aviation industry. International cooperation among different government and private initiatives for the research and development of aviation biofuels has already begun, which could possibly lead to consensus in the future on sustainability requirements.

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10. Appendices

Interview questions for industry stakeholders

1. When it comes to aviation biofuels, which stakeholders do you collaborate with?
2. How is the use of GMO-based biofuel perceived by your stakeholders?
3. Do you believe aviation would benefit from considering 1st generation biofuels?
4. Which aspects of biofuels need further research to increase their sustainability?
    a. Which stakeholders could contribute to these?
5. How is the incompatibility of the US RFS and EU RED perceived by your stakeholders?
    a. How does this influence the spread of biofuel use within aviation?
6. How do the stakeholders working with your organization achieve a consensus on how sustainable biofuels should be defined?
7. Does the price competitiveness of alternative fuels as ctl or gtl are gaining popularity among end-users?
    a. Does this pose a risk to biofuel development?
8. What is your opinion about waste-based biofuels and the opportunities they have?