ALTERNATE FUEL FOR AIRCRAFTS

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A Declaration by the Guide on Company Letter Head

This is to certify Ms Aida Alex a student of Executive BBA (Program), Roll No 500031531 of UPES has successfully completed this dissertation report on "**ALTERNATE FUEL FOR AIRCRAFTS**" under my supervision. Further, I certify that the work is based on the investigation made, data collected and analyzed by her and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of Executive BBA.

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Table of Contents

Acknowledgment.. I

Table of Contents..IV

List of Tables and Illustrations...VI

List of figures..VII

Acronyms & Abbreviations...VIII

Executive Summary / Abstract..XI

CHAPTER 1: INTRODUCTION 1
- 1.1 OVERVIEW.. 4
- 1.2 BACKGROUND.. 5
- 1.3 PURPOSE OF THE STUDY 7
- 1.4 RESEARCH HYPOTHESIS 9

CHAPTER2: LITERATURE REVIEW 10
- Literature review.. 11
- 2.1 REVIEW AREA BROAD 12
- 2.2 REVIEW AREA NARROW.. 31
- 2.3 FACTORS CRITICAL TO SUCCESS OF STUDY.. 44
- 2.4 SUMMARY.. 45

CHAPTER 3: RESEARCH DESIGN, METHODOLOGY AND PLAN 46
- 3.1 DATA SOURCES 47
- 3.2 RESEARCH DESIGN 48
- 3.3 DATA ANALYSIS PROCEDURES 50

CHAPTER 4: FINDINGS AND ANALYSIS 52
- 4.1 FINDINGS & ANALYSIS.. 53
- 4.2 CORRELATION/ REGRESSION ANALYSES.. 57

CHAPTER 5: INTERPRETATION OF RESULTS 58
- 5.1 INTERPRETATION OF RESULTS 59
- 5.2 Comparison of Results with Assump ons (Hypotheses) 61

CHAPTER 6: CONCLUSION AND SCOPE OF FUTURE WORK 62

Bibliography 66

References 67

List of Tables and Illustrations

1. Environmental trends assessment to2040 26
2. Can alternative jet fuel be price competition 49
3. Availability and usage of fuels 52
4. Fuels price analysis 54

List of Figures

1. Certification of alternative fuels 14
2. A S T M D4054 Qualification process 15
3. A T J – S p k process description 16
4. Eco – skies aircraft 22
5. Co_2 emission reduction 27
6. Schematic representation of well-to wake life cycle analyze 32
7. KLM'S Bio fuels programmer partner 36
8. Partners of KLM'S Bio fuels program 37
9. Sky NRG 38
10. Air Canada 40
11. The life cycle of bio fuels production 42

ACRONYMS & ABBREVIATIONS

AEMP = Annual Emissions Monitoring Plan
AER = Annual Emissions Report
AFRL = Air Force Research Laboratory (USA)
ASTM = American Society of Testing and Materials (USA)
ATA = Air Transport Association (USA)
BTL = Biomass to Liquids (Fischer-Tropsch process)
BTU = British Thermal Unit
CAA = Civil Aviation Authority
CAAFI = Commercial Alternative Aviation Fuels Initiative (USA)
CO2 = Carbon Dioxide
CTL = Coal to Liquids (Fischer-Tropsch process)
DLA = Defense Logistics Agency (USA)
DOE = Department of Energy (USA)
EC = European Commission
EPA = Environmental Protection Agency (USA)
ETS = Emissions Trading Scheme
EU = European Union
EUA = European Union Emission Allowance
EUAA = European Union Aviation Emission Allowance
FT = Fischer-Tropsch process
FAA = Federal Aviation Administration (USA)
FAE = Fatty Acid Ester
FAEE = Fatty Acid Ethyl Ester
FAME = Fatty Acid Methyl Ester
GE = Gasoline Equivalent
GHG = Greenhouse Gas
GTL = Gas to Liquids (Fischer-Tropsch process)
HEFA = Hydroprocessed Esters and Fatty Acids
HRJ = Hydroprocessed Renewable Jet fuel
ICAO = International Civil Aviation Organization
IEA = International Energy Agency

LCA = Lifecycle Analysis

LGE = Liters of Gasoline Equivalent

MJ = Megajoule

OEM = Original Equipment Manufacturer

PARTNER = Partnership for Air Transportation Noise & Emission Reduction

PPP = Public Private Partnership

RED = Renewable Energy Directive (EU)

RFS = Renewable Fuel Standard (USA)

RSB = Roundtable on Sustainable Biofuels

SPK = Synthetic Paraffinic Kerosene

SWAFEA = Sustainable Way for Alternative Fuels and Energy in Aviation

USAF = United States Air Force

Abbreviations

Alternative fuel = fuel from non-petroleum source

ASTM D1655 = ASTM Standard Specification for Aviation Turbine Fuels

ASTM D7566 = Standard Specification for Aviation Turbine Fuels Containing Synthesized Hydrocarbon

Bio fuel = fuel produced out of biomass
Bio jet fuel = jet fuel produced out of biomass

BTL= biomass to liquid

CO2= carbon dioxide

Drop-in fuel = alternative fuel that is indistinguishable from conventional fuel, with no changes of air craft, engine or supply infrastructure required

FT fuel = fuel produced with the Fischer Tropsch process
Fuel additive = additive to fuel to improve a certain property

Gallon = 3.785 Litres

Hydrocarbons = molecules made out of carbon and hydrogen, used as fuels
Hydro cracking = cutting down carbon chains under influence of hydrogen
Hydrogenated = raw material upgraded by hydro processing
Hydro treatment = saturating and removing impurities in hydrocarbons using hydrogen
Hydro processing = upgrading of oils with hydrogen, current technology in refineries

PARTNER = Partnership for Air Transportation Noise and Emission Reduction

SPK = Synthetic Paraffinic Kerosene, jet fuel substitute lacking aromatic compounds
Sustainable biomass = renewable and environmentally friendly biomass.

Executive Summary / Abstract

The alternative jet fuels sector has remained quite active over the last year with new initiatives launched for their promotion and development and with an increasing number of countries expressing interest. Airlines and major aircraft manufacturers have been strongly involved in these initiatives, aiming at securing a future supply of sustainable aviation fuels. Technology developments are also increasing with an impressive number of technology companies at work and numerous processes being developed or proposed for approval. Prospective alternative jet fuel producers spent 2013 generating the technical data necessary to support the ASTM International qualification process for their new fuels. Four of these producers or groups of producers have made sufficient progress in the ASTM qualification process to issue ASTM research reports for review by key aviation fuel community stakeholders. These reports contain technical data describing the fuel composition, properties, and performance in aircraft engines and test rigs. It is anticipated that the ASTM International process to review, ballot, and issue annexes for the drop-in fuel specification, D7566, will occur for one or more of these new path- ways in 2014.Different sustainability standards are in use for aviation bio fuels, both regulatory and voluntary. Due to the considerable differences between these standards, there is a need for harmonization. Selections of three important standards are reviewed in this report: the Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and US Renewable Fuel Standard (RFS). The RSB has recently certified the first bio jet fuel supplier (SkyNRG) and several aviation bio fuel initiatives have recommended using RSB standards for their bio fuel supplies. The ISCC is the most widely- used of the voluntary certification schemes that are recognized under the European Renewable Energy Directive (RED). The US Renewable Fuel Standard (RFS) provides a very effective incentive system based on tradable certificates (RINs) that are generated for each batch of bio fuel. Bio jet pathways face significant cost challenges. Depending on the details of the particular pathway, the price premium of the bio fuel over conventional jet fuel could be the result of high feedstock costs, high capital expenses, or some combination of the two. There are incentive structures in place in certain countries which help reduce these additional cost burdens for the fuel producer. Energy technology is expected to improve over time due to market competition, experience, and innovation, which should drive down fuel production costs, while conventional jet fuel prices are expected to increase.

CHAPTER 1: INTRODUCTION

INTRODUCTION

Since the energy crisis of the 1970s, almost all of the energy, aircraft, and engine companies, as well as government entities, have been investigating the practicality of using alternative fuels in aircraft, albeit at a relatively slow pace. Because of price and environmental pressures, interest in alternative jet fuels derived from non- petroleum sources is once again growing. Alternative fuels, if available in sufficient quantities, offer the potential to reduce price, mitigate the effects of supply disruptions, and reduce the environmental impacts of aviation. In the U.S., in coordination with international collaborators, the FAA and industry launched the Commercial Aviation Alternative Fuels Initiative (CAAFI) in 2006 to chart a course toward developing and adopting, alternative jet fuels. CAAFI's stated goal is "to promote the development of alternative fuels that offer equivalent levels of safety and compare favourably with petroleum based jet fuel on cost and environmental bases, with the specific goal of enhancing security of energy supply." More specifically, government, industry, academia, and non-profits are working through CAAFI to pursue alternative jet fuels for the purpose of:

- Securing a stable fuel supply.
- Furthering research and analysis.
- Quantifying the ability to reduce environmental impacts.
- Improving aircraft operations CAAFI adopted three high level goals:
- Develop the means to quantitatively differentiate alternative fuels on aircraft platforms.
- Develop methods to quantitatively differentiate alternative fuels at airports on both an environmental and economic basis
- Establish a secure web based means of communication within the enterprise.

CAAFI has held multiple conferences and facilitates ongoing communication among stakeholders to develop and share data with the various elements of the aviation supply chain. This process is guided by four teams focused on the specific areas of research and development; commercialization; environmental impacts and fuel certification. Early findings from these interactions include:

1) The aviation industry is interested in the possible savings and price stability offered by alternative fuels;

2) industry is willing to produce these fuels if there is a viable market for them; and, 3) industry and regulators may be able to use alternative fuels to mitigate air quality issues, thus allowing engine designers to focus on other environmental concerns such as noise and climate change. U.S. Federal Aviation Administration (FAA) is pursuing a number of studies to address the following points to address questions and concerns regarding alternative jet fuels:

- Identify the motivating factors (i.e., drivers)
- Clarify technical feasibility
- Quantify environmental benefits
- Identify the needed infrastructure to support transition
- Qualify and certify fuels
- Determine what, if anything should be done to promote alternative jet fuels the sections below outline progress on these efforts. This paper discusses some of the motivating factors that are pushing aviation toward alternative jet fuels. It then presents results of recent studies weighing the technical feasibility and environmental benefits and costs of alternative jet fuels. It also includes an update on certification activities.

1.1 OVERVIEW

The convergence of high fuel prices with possible caps on harmful aircraft engine emissions has encouraged the aviation community to investigate alternatives to petroleum-based jet fuels that would be safe and cost-effective--both to use and produce. In 2006, for the first time in history, fuel became the single largest component of U.S. airline operating cost. According to the Air Transport Association (ATA), while consumption by commercial aircraft has stayed steady over a seven year period at about 20 billion gallons per year, jet fuel expenses have more than doubled over that same period. The aviation industry has achieved substantial improvements in fuel efficiency since the introduction of commercial jet aircraft in the 1960s through fleet modernization, air traffic management improvements and operational changes. However, despite such improvements, expectations of increased fuel consumption from projected growth in air travel and the possibility of higher fuel prices are forcing the aviation industry to try to reduce its reliance on fossil fuels and find alternative sources of supply. So far, alternative fuels being considered for aviation include synthetic fuels, such as those produced using a process called Fischer- Tropsch, and a number of bio fuels. While synthetic fuels made from coal, natural gas and other hydrocarbon feedstock are attractive because they can be easily integrated into existing aircraft systems, such fuels do not help address climate issues and as such are viewed by some as only near-term alternatives. In contrast, bio fuels produced from a wide variety of plant material are characterized as ``carbon neutral" and thus may help mitigate the impact of aviation on the environment.

First-generation bio fuels, commonly made from fermented sugars from wheat or corn; soy beans; and sunflower seeds are generally unsuitable for aviation jet fuel. If bio fuels are to become successful in commercial aviation use, they will need to be high in energy, safe to use, capable of working well in sub-zero temperatures at high altitudes, cost-efficient to make, suitable for production in large quantities, and capable of burning cleanly.

Of late, there has been significant activity in the development and testing of bio fuels for aviation. U.S. research in the application of bio fuels for aviation is being conducted by the National Aeronautics and Space Administration (NASA); the Department of Defense (DOD); a consortium of the Federal Aviation Administration (FAA), airlines and aircraft manufacturers; and other partnerships. The airline industry views the primary benefit of using bio fuels as being the enhancement of the industry's ability to reduce greenhouse gases throughout the fuels' entire life cycle.

1.2 BACKGROUND

In under a decade, sustainable alternative fuels have emerged as a promising solution to limit aviation's greenhouse gas (GHG) emissions. Alternative fuels are among the basket of measures considered by ICAO Member States to contribute to the achievement of the global as operational goal of stabilizing GHG emissions from international aviation at 2020 levels. Indeed, while reducing fuel consumption through technological and operational improvements remains instrumental to limiting the impact of aviation on the environment, the anticipated gains in efficiency do not fully offset the expected increase in fuel consumption resulting from the forecasted growth of air traffic for the next 40 years. When produced from renewable sources or waste, alternative fuels have the potential to bring substantial GHG emissions reductions on a life cycle basis, and may thus close part of this gap.Considering the potential benefits of using sustain- able alternative fuels in aviation and the sustained effort required for their development, ICAO convened the Conference on Aviation and Alternative Fuels.

Rio de Janeiro in November 2009 inviting States to further work together through ICAO to share their efforts and strategies to accelerate the development and deployment of alternative fuels for aviation. The use of sustainable alternative fuels was endorsed as an important means of reducing aviation emissions and ICAO was tasked with facilitating and supporting initiatives for the development and deployment of these fuels, in particular the Conference adopted the ICAO Global Framework for Aviation Alternative Fuels (GFAAF) as a means of information exchange and dissemination.

A major step for sustainable alternative fuels in aviation was the approval in 2009 of the first "drop-in" fuels, i.e. fuels that are fully compatible with existing systems and that can be used just as if they were conventional fuel with no limitations in aircraft operations. The effort to develop alternative fuels with molecules and properties similar to conventional Jet A-1 ensured compliance with the stringent aviation requirements on fuel properties. As a result, the safety of operations was preserved, and any cost impact that may have been incurred due to a change in infrastructure, was avoided.

After the first approval of Fischer-Tropsch fuel in 2009, the approval of Hydro processed Esters and Fatty Acids (HEFA) by ASTM in 2011 opened the door to the first commercial use of sustainable alternative fuels in aviation. The number of commercial flights using HEFA fuel multiplied and, as of June 2012, more than 18 airlines had collectively performed over 1,500 commercial flights, including regularly scheduled flights.

The increase in commercial flights using alternative fuels demonstrated the technical feasibility of these fuels in aviation, and the strong interest of airlines. However, the production of these fuels is still in its early phase with only a limited volume currently available. There are still significant challenges to overcome before these fuels can represent an appreciable share of the global jet fuel supply. This article high- lights the main challenges that need to be addressed and provides an overview of the recent developments worldwide toward commercial scale deployment.

1.3 PURPOSE OF THE STUDY

The purpose of the study is to find out the alternative fuels for aircrafts. While technical feasibility has been established, the price gap with conventional jet fuel in the short term is the major hurdle to stimulate the commercial deployment of alternative fuels in aviation. Economic assessments of alternative fuels for aviation converge on an initial lack of competitiveness compared to conventional jet fuel, which is likely to continue during the initial development phase before best practices, progress in production technology and economies of scale can bring about meaningful cost reductions. Incentives, or compensation mechanisms for the environmental benefits of using these fuels, are required to bridge the price gap in order for airlines to want to buy the fuels; in most cases they are nevertheless not in place. These results in a lack of a clear market perspective, which is needed to encourage investment in an emerging sector which is still perceived as being high risk.

An additional hurdle for alternative fuels in aviation is that a level playing field does not exist with the road transportation sector. Renewable energy policies in most countries support the deployment of bio fuels for road transport through mandatory production quotas and fiscal incentives. In order for fuel producers to consider the aviation market, where technical requirements for fuels are more stringent, it is important that policies also consider the use of supporting measures for sustainable alternative fuels in aviation. In defining such policies, the time frame and investments required to develop the industry need to be kept in mind. Stability and long term perspective are key requirements to improving confidence and attracting investors.

Beyond supporting measures, a key to the deployment of alternative fuels in aviation is to bring costs on par with fossil fuels. This requires improving efficiency and reducing the costs of both transformation processes and feedstock production, which will necessitate further support and investments in research and development, as well as the demonstration and scale-up of technologies.

Ensuring the sustainability of deployment is also a major concern for aviation. The potential of alternative fuels for GHG emissions reductions is a strong motivator for their introduction into commercial aviation operations. Moreover, the aviation community has demonstrated its commitment to the environmental, social and economic pillars of the sustainability of alternative fuels. A large number of aviation stake- holders are represented in organizations such as the Round-table for Sustainable Biomaterials (RSB) and the Sustainable Aviation Fuel User

Group (SAFUG), which aim to promote sustainable practices in agricul- ture and energy biomass production.

The voluntary certification of alternative fuel production chains, as already initiated by some stakeholders and bio fuel projects, is part of the solution for the development of sustainable alternative jet fuels. Yet, not all of the impact of deploying alternative fuels on a commercial scale can be measured at the individual production-chain level. Therefore, there is a need for sustainability issues to be addressed at a more global level in States' policies, including at the decision- making level, in the development and implementation of sustainable bio fuel policies and strategies, and in monitoring the impacts of the developments as promoted by the Global Bio energy Partnership (GBEP), through the definition of a set of sustainability indicators for bio energy production. Indirect impacts of developing alternative fuels, such as on the global food market or land use change in other regions due to displacement of previously existing crops, also needs to be considered, which may require specific policy measures, as well as additional methodologies and research, as there is currently no consensus on these issues.

In the efforts to ensure sustainability, given the global nature of international aviation, the emergence of different systems and regulations may cause additional challenges. Increased harmonization and the definition of mutual recognition mechanisms would be desirable to facilitate the deployment of alternative fuels on a commercial scale.

Last, sustainability is an important aspect of the long term challenge of producing sufficient quantities of feedstock for the commercial scale deployment of alternative fuels in aviation. Research in agriculture and new feed stocks, as well as on innovative processes such as those that eventually will not use biomass, remains a major axis to pursue, together with improved assessments of biomass potential, in order to establish the roadmap toward making a significant contribution to aviation's objective to limit emissions .

1.4 RESEARCH HYPOTHESIS

The hypothesis of this research is, to determine whether the long term benefits of alternative fuel outweigh the cost of implementation when compared to the current running costs of traditional jet fuel i.e. AVTUR. Specifically would it be cheaper to use bio jet fuels in aircraft operations instead of AVTUR in the future?

CHAPTER2: LITERATURE REVIEW

Literature review

A literature review is a text of a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. Literature reviews use secondary sources, and do not report new or original experimental work. Most often associated with academic-oriented literature, such as a thesis, dissertation or peer-reviewed journal article, a literature review usually precedes the methodology and results section. Literature reviews are also common in a research proposal or prospectus (the document that is approved before a student formally begins a dissertation or thesis). Its main goals are to situate the current study within the body of literature and to provide context for the particular reader. Literature reviews are a staple for research in nearly every academic field. A systematic review is a literature review focused on a research question, trying to identify, appraise, select and synthesize all high quality research evidence and arguments relevant to that question. A meta-analysis is typically a systematic review using statistical methods to effectively combine the data used on all selected studies to produce a more reliable result.

2.1 REVIEW AREA BROAD

The alternative jet fuels sector has remained quite active over the last year with new initiatives launched for their promotion and development and with an increasing number of countries expressing interest. Airlines and major aircraft manufacturers have been strongly involved in these initiatives, aiming at securing a future supply of sustainable aviation fuels. Technology developments are also increasing with an impressive number of technology companies at work and numerous processes being developed or proposed for approval.

Although routine production of bio-jet fuels is expected as of 2014, there is still a long road ahead before a significant volume of fuel could be made available for commercial aviation. This will require the expansion of supporting policies by countries to address, in particular, the price gap with conventional jet fuels while taking sustainability into account.

The reaffirmation of support from States through ICAO's Resolution on climate change and the increased·number of activities and partnerships are positive signs of the willingness to foster development in this rapidly evolving sector. Cooperation among aviation stakeholders and other players from the bio energy sector will in particular be keys to addressing sustainability issues and securing access of aviation to sustainable fuels.

While the recent past was marked by a series of commercial flights, the number of flights operated with alternative fuels was noticeably lower over the last year, corresponding to the fact that there is no routine production of sustainable alternative jet fuel at competitive price. To date, commercial flights have operated with especially produced batches of fuels (existing hydro processing plants for vegetable oils and animal fats are mostly dedicated to diesel fuel). Prospective alternative jet fuel producers spent 2013 generating the technical data necessary to support the ASTM International qualification process for their new fuels. Four of these producers or groups of producers have made sufficient progress in the ASTM qualification process to issue ASTM research reports for review by key aviation fuel community stakeholders. These reports contain technical data describing the fuel composition, properties, and performance in aircraft engines and test rigs. It is anticipated that the ASTM International process to review, ballot, and issue annexes for the drop-in fuel specification, D7566, will occur for one or more of these new path- ways in 2014.

ASTM Approval Process for Alternative Jet Fuel

ASTM D7566 was issued in September, 2009. This specification only includes fuels that possess essentially identical compositions and performance properties to petroleum-derived Jet A/A1 fuel. These fuels are called drop-in fuels. The specification is structured with annexes that define property and compositional requirements for synthetic blending components that can be mixed with conventional, petroleum-derived jet fuel at specified volumes to result in fully-formulated drop-in fuels. It currently includes two annexes for approved drop-in fuels; Fischer Tropsch (FT) and Hydro process Esters and Fatty Acids (HEFA), that can blended at up to 50% volume with petroleum- derived jet fuel. D7566 includes a provision to allow fuels meeting this specification to be re-identified as conventional fuels when they enter the distribution infrastructure. ASTM International Standard D1655, 'Standard Specification for Aviation Turbine Fuels' defines the requirements for petroleum derived, conventional jet fuel. This re-identification provision allows the drop-in fuels listed in D7566 to be seamlessly integrated into the infrastructure and on to the aircraft without the need for separate tracking or regulatory approval. This is because the infrastructure is already designed to support D1655 jet fuel, and virtually all civil aircraft include "ASTM D1655 Jet A/A1 fuel" as an operating limitation and are therefore certified to operate with jet fuel meeting specification D1655. So, once a new alternative jet fuel is added as an annex to D7566, it is fit to fly on commercial airliners because it meets the existing approved aviation fuel operating limitation. Fuels that are found not to be drop-in fuels do not meet the existing approved operating limitation and must therefore undergo a separate regulatory approval process following the ASTM International qualification process.

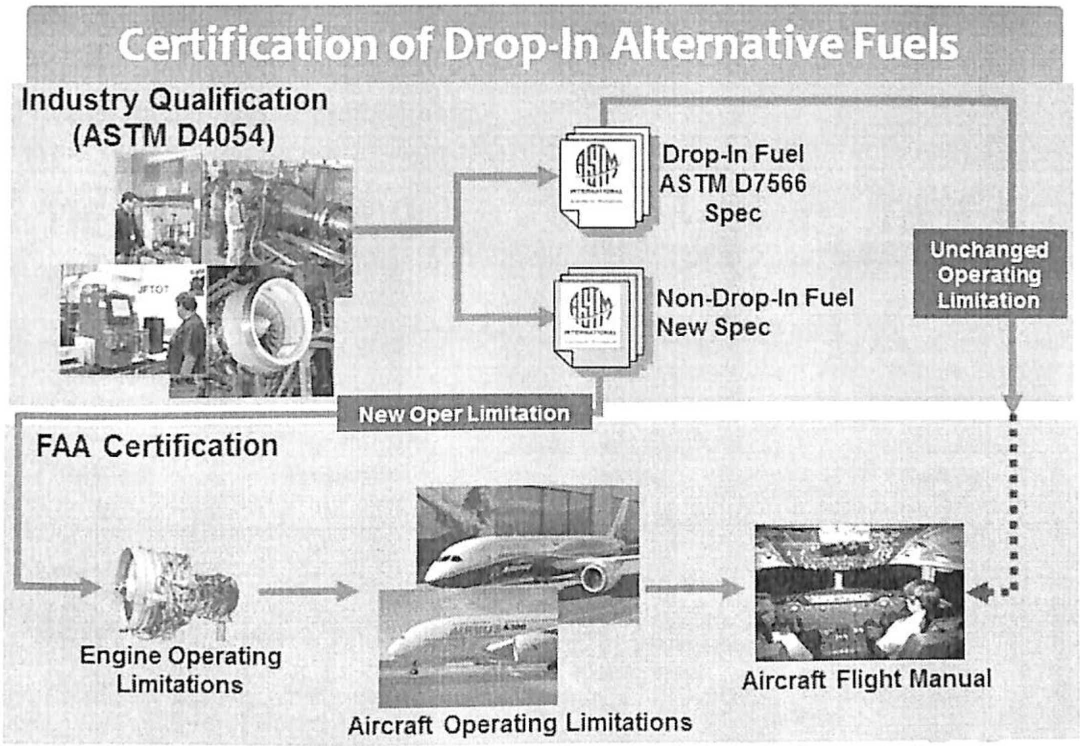


Figure 1: certification of alternative fuels.

ASTM D4054 was developed to provide the producer of an alternative jet fuel with guidance regarding testing and property targets necessary to evaluate a candidate alternative jet fuel. D4054 is an iterative process, which requires the candidate fuel devel- oper to test samples of fuel to measure properties, composition, and performance. The testing covers basic specification properties, expanded properties called fit-for-purpose (FFP) properties, engine rig and component are testing, and if necessary, full-scale engine testing (see Figure 3). This is a rigorous process that requires participation and input from many of the stakeholders at ASTM.

Typically, a producer will be seeking approval of a synthetic blending component for incorporation into D7566 as a new annex. A preliminary specification that lists the controlling properties and criteria for the neat synthetic blending component should first be established by the fuel producer prior to the initiation of the D4054 test program. The D4054 data is used to demonstrate that the proposed specification properties are sufficiently robust to ensure that all synthetic blending components meeting those properties will be fit-for-purpose for use on turbine engines and aircraft when blended with conventional jet fuel. The D4054 data must also substantiate that the proposed specification properties adequately control the blending component performance when subjected to the process variability that is expected to occur during large-scale production. The D4054 data and the proposed specification properties are then used as the basis for development of a proposed annex for incorporation into D7566 as a drop-in synthetic jet fuel. The iterative nature of this process evolves from the re-adjustment of the initial proposed specification properties that typically occurs upon review of the D4054 test results by the ASTM membership.

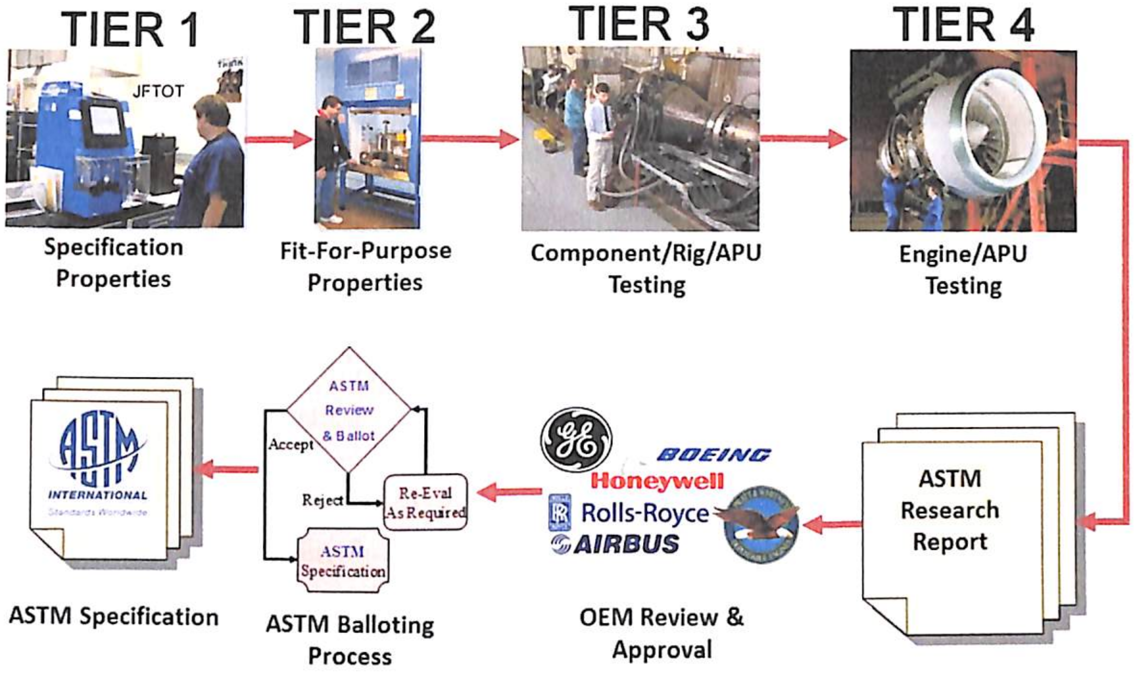


Figure 2: A S T M D4054 Qualification Process.

ASTM Research Report Overview

There are currently four draft ASTM Research Reports that are under review by key aviation fuel stake- holders in preparation for balloting to the entire ASTM membership. The ASTM task forces that submitted these reports are: Fischer-Tropsch Synthetic Kerosene with Aromatics (FT-SKA) Alcohol to Jet (ATJ) Hydro processed Depolymerised Cellulosic Jet (HDCJ) Direct Sugar to Hydrocarbon (DSHC)Ê

The data contained in these reports provides the information necessary to determine if the proposed feedstock and conversion pathway produces a fuel that is fit-for-purpose (FFP) for aviation use. In essence, the fit-for-purpose of a new fuel is determined by comparison to the existing, petroleum-derived Jet A/ A1 fuel. The following is a brief overview of the typical content of these research reports with examples of that content.

Process Description

ASTM Research Reports typically start with an over- view of the pathway, or process that is used to produce the new fuel. A description of feedstock requirements, process steps, and intermediary products is provided (see Figure 4 for an example). The process description is important because it is used to establish the control- ling definition of the fuel which will be specified in the D7566 specification annex.

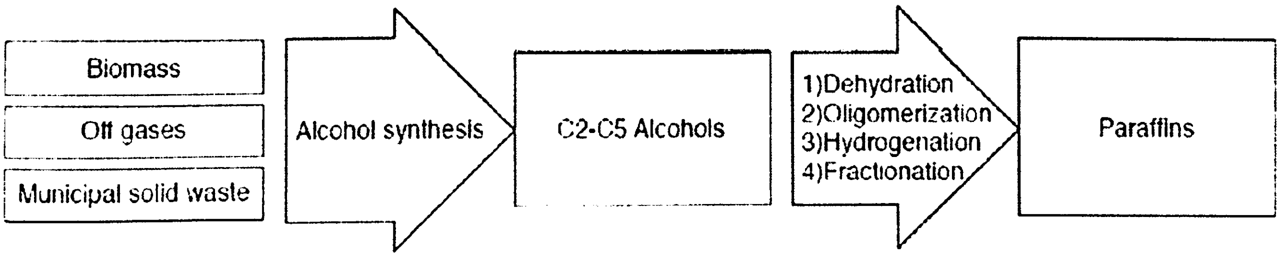


Figure 3: ATJ- S p k process description

Tier 1 and 2 Data Section

The data analysis section of the report typically addresses the Tier 1 and 2 requirements of D4054. This section includes both tabular and graphic descriptions of fuel composition, including trace materials, of the neat, unblended synthetic fuel. This testing can be completed with relatively small volumes of test fuel ranging from 10 to 80 gallons. Sources of the fuel samples are carefully identified to facilitate presentation of data throughout this section. Figure 5 shows a chromate gram that shows the size distribution of hydrocarbon molecules that comprise the neat ATJ fuel samples. The distribution of the hydrocarbon molecules is important to ensure

proper combustion in the turbine engine. This section also provides data describing the specification and FFP property test results from the laboratory tests defined in ASTM D4054. Testing results for both the unblended synthetic fuel and the blended jet fuel are provided, as applicable. Figure 6 shows the viscosity of blends of HDCJ fuel and petroleum-derived jet fuel over the operating range of aircraft engines. As can be seen in the figure by the location of the stars which represent the HDCJ samples, the HDCJ fuel is within the jet fuel experience base. This ensures that the new fuel will flow and pump properly in engines designed to operate on petroleum-derived jet fuel.

Different sustainability standards are in use for aviation bio fuels, both regulatory and voluntary. A selection of the most relevant standards is described in more detail in this chapter. Due to the considerable differences between these standards, there is a need for harmonization.

The three standards reviewed in this chapter are the Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and US Renewable Fuel Standard (RFS). The RSB has recently certified the first bio jet fuel supplier (SkyNRG) and several aviation biofuel initiatives have recommended using RSB standards for their biofuel supplies. The ISCC is the most widely-used of the voluntary certification schemes that are recognized under the European Renewable Energy Directive (RED). The US RFS provides a very effective incentive system based on tradable certificates (RINs) that are generated for each batch of biofuel.

Throughout the history of aviation there has been a continuous improvement of fuel efficiency, driven by the necessity to save weight and costs, and increasingly by environmental considerations. Only in the last decade have possibilities emerged to replace conventional jet fuel by more sustainable alternatives.

Following developments in land transport, biofuels became a promising choice of a sustainable alternative energy for aviation because of their reduced net carbon dioxide emissions compared to fossil fuels. For aviation there are no other sustainable alternative energies available in the near-to-mid-term, contrary to the automotive sector which already offers solutions using electric batteries and fuel cells. It is however essential that, in addition to greenhouse gas savings, other environmental, societal and economic aspects of sustainability are also respected in biofuel produc- tion and use. Influenced by the experience with poor sustainability of various first-generation biofuel feed- stocks for land transport, the aviation industry has been focusing on sustainability as a main requirement from the beginning of their engagement in biofuels.

There are a variety of regulatory and voluntary sustain- ability standards that are applicable to aviation biofuels. The present chapter reports on the latest develop- ments in some of them.

Biofuel sustainability regulations in force in various countries show considerable differences in scope and procedures, especially between the EU RED and the US RFS. An example of this are the methodologies used to determine lifecycle greenhouse gas emissions. For aviation as a global activity it is essential to remove obstacles stemming from such regulatory differences to enhance the uptake of biofuels by airlines.

The United Nations International Civil Aviation Organization (ICAO) supports this need, and its Sustainable Aviation Fuels Expert Group (SUSTAF) has made respective recommendations to the 38th ICAO Assembly, held in Montréal in September / October 2013. The ICAO

Resolution A38-18 on Climate Change strongly promotes the use of sustainable alternative aviation fuels and contains a number of requirements to ensure the sustainability of these fuels.

A landmark agreement on Climate Change was reached with the ICAO Resolution 38-18. The agreement commits ICAO to developing a global market based measure that will be an essential enabler for the industry to achieve carbon neutral growth from 2020. The agreement will set in motion the detailed design elements for the monitoring, reporting and verification of emissions and the type of scheme to be implemented. It was agreed to apply the ICAO guiding principles when designing MBMs in an effort to avoid duplication, carbon leakage and market distortions and address non-discrimination. Full resolution details can be found elsewhere.

Conventional Jet Fuel Price Development and Incentives for Alternative Fuels as Points of reference

Alternative aviation fuels compete with conventional jet fuel from petroleum. Airlines operate in a highly competitive, low-margin market and can be expected to refrain from large-scale usage of alternative fuels if they are not cost-competitive with the conventional counterpart. This does not necessarily imply that these fuels need to be competitive on their own in the short term, since there are policies in place that give incentives to produce and use alternative aviation fuels. Although the renewable volume obligations (RVO) specified by RFS2 do not require production of renewable jet fuel, it can qualify for a renewable identification number (RIN)12, which can be traded and used by obligated parties to satisfy renewable fuel mandates. At current prices, RINs can offset the cost differential between alternative and conventional jet fuel by $0.26/L ($1/gal). However, because separating jet fuel from diesel fuel requires additional processing, RFS2 is more likely to incentivize biomass-based diesel production over biojet.

While there is considerable uncertainty about the future price of conventional jet fuel, prices are generally expected to increase in the coming decades due to increased global demand for crude. Biojet pathways face significant cost challenges. Depending on the details of the particular pathway, the price premium of the biofuel over conventional jet fuel could be the result of high feedstock costs, high capital expenses, or some combination of the two. There are incentive structures in place in certain countries which help reduce these additional cost burdens for the fuel producer. Energy technology is expected to improve over time due to market competition, experience, and innovation, which should drive down fuel production costs, while conventional jet fuel prices are expected to increase.

Swedish Biofuels

The EU has demonstrated increased interest in the greening of the aviation industry with substantial financial support for the Swedish Biofuels' technology that converts biomass to jet fuel via alcohols. A pre-commercial industrial scale plant with an annual capacity of up to 10,000 tonnes of aviation fuel and diesel will be constructed.

International Consortium

Swedish Biofuels AB will coordinate an international consortium over the next five years with the goal of producing paraffinic biofuels for use in aviation.

The consortium consists of organisations with the capability of supplying raw materials, designing, constructing, and operating a pre-commercial industrial scale plant for the production of fully synthetic jet fuel. Consortium members will also offer the possibility of testing the biofuel in aircraft systems. Within the scope of the project, environmental Life Cycle Assessments (LCA) will be carried out. The members of the consortium are Swedish Biofuels (SE, jet fuel production process), Abengoa (ES, municipal solid waste to ethanol), Lufthansa (DE, engine testing and flight),

SkyNRG (NL, marketing), E4Tech (CH, life cycle analysis), SCA (SE, raw material supply), Rameski Keskus (EE, equipment), Perstorp (SE, industrial site), Lanza-Tech (UK, syngas to ethanol) and Vrije Universiteit Brussel (BE, policy studies).

The capacity of the plant will be 10,000 tonnes per year, of which 50% consists of jet fuel, the rest being the byproducts aviation gasoline (AVGAS) and diesel. The jet fuel produced will be compatible, without blending, with in-service and envisaged jet engines for both civilian and military applications. It will consume a variety of sustainable raw materials focusing on wood, municipal solid waste and biogas.

Biomass to Jet Fuel Via Alcohols

Less than ten years ago, any suggestion of producing jet fuel from biomass was met with incredulity. At that time Swedish Biofuels considered jet fuel as a possible, but risky, extension to its product development of drop-in diesel and gasoline. This changed in 2006 when the Defence Advanced Research Project Agency (DARPA) contracted Swedish Biofuels to demonstrate its technology for producing a 100 % biological equivalent to JP-8 jet fuel. By 2008, Swedish Biofuels demonstrated this technology, at laboratory scale.

A central feature of the technology is that cellulose, lignocellulose, or some other carbon source, is used as the starting point, the pathway to jet fuel includes the production of alcohols (C2 - C5) and synthesis gas as intermediate products. The key technology achievements are catalysts and processing units capable of producing the complex end product. It was necessary to find ways of producing hundreds of hydrocarbon compounds in order to mimic the properties of military spec jet fuel (JP-8). Systems were developed for synthesizing highly branched paraffins, mono-aromatics and cyclic compounds with particular attention on minimizing the projected cost of full scale production.

Today the alcohol to jet concept is in operation at a pilot plant, which has been in continuous operation for the past two years, producing fully synthetic paraffinic jet fuel. The pilot plant is located at Swedish Biofuels laboratories at the Royal Institute of Technology (KTH) in Stockholm, Sweden. The pilot plant has a capacity of 10 tonnes per year of production of the final products of jet fuel 4.8 tonnes per year, gasoline 3.5 tonnes per year and diesel 1.7 tonnes per year.

Certification

The jet fuel produced at the pilot plant, under the code name SB-JP8, is currently being tested by the US Air Force (USAF), as part of a large scale programme to introduce and certify alternative fuels. SB-JP8 has successfully passed all tests to date and the data has been submitted to the relevant ASTM International committee for certification of the fuel for commercial use.

Climate Change, Global Warming, Pollution, Sustainability, Food Shortage, Growing World Population and you-name-it-Green; subjects that we read about almost daily in the media and issues that concerns us all. Most human activities in our society and daily life cause GHG emissions and pollution and aviations no exception (2% to 3% of the total, global manmade CO2 emissions). Consequently, we hear voices stating "stop flying, it pollutes" and "the world is in financial crisis, we can't afford investing in a transition to alternative energy, away from a society based on fossil fuels". To quote James Hansen of NASA "Global warming is not a problem for the future; it's a crisis for this moment! - It's a task for our generation!" The good news is that aviation is being extremely proactive in efforts to reduce such CO2 emissions by introducing new aircraft and engine technology as well as new operational procedures and alternative fuels.

The latest IPCC report underlined and emphasized that we are moving too slowly and we shall have difficulties to keep even the maximum 2 degrees Celsius ceiling that the UN and many others have set as the "acceptable" increase in average global temperature before we reach a "point of no return". This is further recognition and confirmation of the seriousness of this issue.

Environmental Impacts of Aviation

There is pressure on the aviation sector to reduce greenhouse gas (GHG) emissions. Aviation contributes approximately 2 percent of the world's carbon dioxide (CO2) emissions (Penneretal., 1999) but has received considerable attention regarding these emissions. For example, in November 2007, the European Parliament voted to bring aviation into the European GHG emission trading system. The legislation would take effect in 2011, and it would require that all airlines flying within or into Europe cut their GHG emissions by 10 percent or buy CO2 allowances on the open market (Roosevelt, 2007; Wald and Kanter, 2007).

In Europe, and especially in the United Kingdom (UK), public demonstrations and legislation show the pressure on aviation to reduce its GHG emissions. Airport expansion in the London area is a concern for the UK government; a recent white paper by the British government estimated that congestion at UK airports costs the UK economy £1.7 billion per year, whereas increasing capacity will benefit the economy by £13 billion (Milmo, 2007). In November 2006, a project to build a second runway at Stansted Airport near London was blocked by the local government on the grounds that it would contribute to global Climate change ("Stansted Expansion Plan Refused," 2006). In August 2007, more than 1,200 protesters descended on London's Heathrow Airport to try to block expansion on the basis of global warming ("Flying and Climate Change," 2007; Roosevelt, 2007). In two separate incidents in February 2008, protestors violated security at Heathrow, climbed onto an airplane, and then mounted a banner onto the aircraft to protest expansion, on the grounds of climate change; a few days later, protesters violated security at the UK Parliament and unfurled a similar protest banner from the roof of the building ("Climate Protest on Heathrow Plane," 2008; "Parliament Rooftop Protest Ends." 2008).

In the United States, aviation has been under less pressure to reduce its GHG emissions than in Europe, but that may be changing. In December 2007, the attorney general of the state of California filed a petition with the U.S. Environmental Protection Agency (EPA) "to crack down on rising aircraft emissions that contribute to global warming" (Roosevelt, 2007). The petition was submitted in association with the states of Connecticut, New Jersey, New Mexico, and Pennsylvania, as well as air-pollution officials from New York City, the District of Columbia, and Southern California.

Figure 4: eco-skies aircraft

Roundtable on Sustainable Biomaterials

2013 has seen steady progress on biofuel sustain- ability in aviation through wider commitment to the RSB standard and the first RSB-certified biojet coming online. The Natural Resource Defense Council called for stronger commitment to the RSB by the sector and Midwest Sustainable Aviation Biofuels Initiative (MASBI) recognized the standard in its findings. The RSB multi-stakeholder process has also endorsed an approach to address the indirect impacts of biofuels which will allow airlines to identify RSB certified fuels that have not displaced food production or led to the destruction of natural habitats. The months ahead look set for further progress on sustainability as the RSB- Boeing initiative to encourage certification of small farmers picks up speed.

It has been a busy year for RSB with a newly inde- pendent secretariat being established in Geneva, the expansion of scope of the standard into bioma- terials and the adoption of a new name "Roundtable on Sustainable Biomaterials". The expansion of scope allows the certification of other forms of bioenergy such as biogas as well as a range of materials produced from biomass including bio-plastics and lubricants. The new Secretariat has been busy streamlining the standard to make it more user-friendly and revising the standard in line with the expansion of scope.

Since the RSB has been extensively described in previous IATA Reports on Alternative Fuels (available on IATA's website), the following sections describe some notable developments that have taken place over the past year.

First RSB-certified Biojet Fuel Now Available

In March 2013, for the first time ever, RSB-certified jet became available with the certification of SkyNRG and its supplier Dynamic Fuels. Dynamic produces drop-in fuels from animal fats, greases, and vegetable oils and SkyNRG supplies more than 15 carriers worldwide including KLM. It provided the biofuel for a series its transatlantic flights from Amsterdam to New York also inaugurated in March.

Biojet Fuel Feedstock Certified in Spain

Camelina Company España (CCE) a joint venture with Great Plains Oil & Exploration became RSB-certified in October. The certification covers over 150 farmers as well as several of Camelina Company's facilities. The camelina is grown as a rotation crop in arid regions of Spain where it does not replace food crops or cause direct or indirect land use change. CCE is part of ITAKA (Initiative Towards sustAinable Kerosene for Aviation) which aims to speed up the commercialization of avia- tion biofuels in Europe. Other ITAKA partners include RSB members Airbus, Neste Oil and SkyNRG.

Sourcing Sustainable Fuels

In a purchasing deal for 57 million litres (15 million gallons) of biojet fuel signed in June, United Airlines stated their support for AltAir Fuels' efforts to incorporate internationally recognized sustainability standards, such as the RSB. In July, Alaska Airlines and Hawaii BioEnergy announced an agreement for the carrier to purchase sustainable biofuel. The feedstock for the biofuel was announced as woody biomass-based and is consistent with RSB sustainability criteria.

Advocating Sustainability

The Natural Resource Defense Council (NRDC) urged the aviation industry to step up its commitment to purchasing RSB-certified fuel to ensure true sustain- ability in the sector. The NRDC report Aviation Biofuel – Sustainability Survey, published in March 2013, provides a detailed independent review of sustainability issues across the sector including potential indirect impacts associated with the supplies of biojet fuels.

Midwest Aviation Sustainable Biofuels Initiative

In the USA, in June 2013 the Midwest Aviation Sustain- able Biofuels Initiative (MASBI) published its findings recommending the use of sustainability criteria consis- tent with international credible standards such as the RSB. This initiative, led by United Airlines, Boeing, the city of Chicago, Honeywell's UOP and Clean Energy Trust, echoes the findings of similar initiatives in Brazil, Mexico, Australia, New Zealand and the US Pacific Northwest.

Brazil Biofuels Platform

RSB Services Foundation, the organisation created and licenced to implement the RSB certification system, has joined with other stakeholders in the Brazil Biojet Platform (BBP) including GOL Airlines, Boeing, Amyris, Solazyme and others as the sustain- ability partner. The goal of the BBP is to bring together stakeholders for integration, optimization and develop- ment of a sustainable biojet fuel supply chain in Brazil. Stakeholders representing technology, feedstock production, airlines, and fuel producers who have joined the initiative will also serve as the private sector interface for US-Brazil Biojetfuel Bilateral Agreement.

Promoting Smallholder Production with Boeing's Global Corporate Citizenship Program

With the help of Boeing's Global Corporate Citizen- ship program the RSB has launched an initiative to promote the integration of the RSB standard into rural development. The program should lead to an increased production of sustainable biofuel while supporting the livelihoods of small farmers. RSB certification is meant to increase the access of smallholders to export markets and to promote sustainable production. The program kicked-off in Southeast Asia with the prepa- ration of a series of case studies to identify difficulties that smallholders experience in becoming certified, and testing a new version of the RSB standard for smallholders.

A workshop in Kuala Lumpur in December 2013 will bring together development agencies and governments to look at how they can integrate RSB certification into rural development programs and improve the liveli- hoods of small-scale farmers. A similar initiative for Latin America will be launched in Mexico in November 2013 and continue in 2014 along with work in Africa. National development agencies in Norway and Swit- zerland are contributing to the smallholder initiative as well as RSB members such as the National Wildlife Federation and the Inter-America Development Bank. Boeing and RSB are seeking additional partners for this initiative.

Ensuring Low Indirect Impact Biofuels

In March 2013, the RSB approved an approach to recognise biofuels with low indirect impact The Assembly of Delegates, which represents the RSB's diverse membership, approved the use of the Low Indirect Impact Bio fuels (LIIB) methodology9 developed jointly by WWF International, Ecole Polytechnique Federal de Lausanne (the former institutional home of the RSB) and Ecofys. The methodology promotes practices that reduce the risk of displacement and competition with food production and biodiversity conservation. Approaches include: the use of wastes and residues, increasing yields, intercropping, and the use of abandoned lands.

Indirect impacts of bio fuels (and biomaterials) have been under discussion for some time with little consensus on how to best address them. Indirect impacts include conversion of natural habitat to agriculture or increased food prices as a result of biomass being diverted for energy. While the existence of such effects is generally accepted, the scale and exact contribution of bio fuels in the recent surge of food prices are heavily disputed. This is why attempts to quantify or model indirect impacts – as in the case of iLUC factors – are subject to controversy

The issue stimulated considerable discussion within the RSB membership and led to an extensive consul- tation process in 2012. The decision by the RSB membership will allow for operators undergoing certi- fication to opt for a voluntary module that will verify that their fuel or biomaterial has low risk of causing indirect impact.

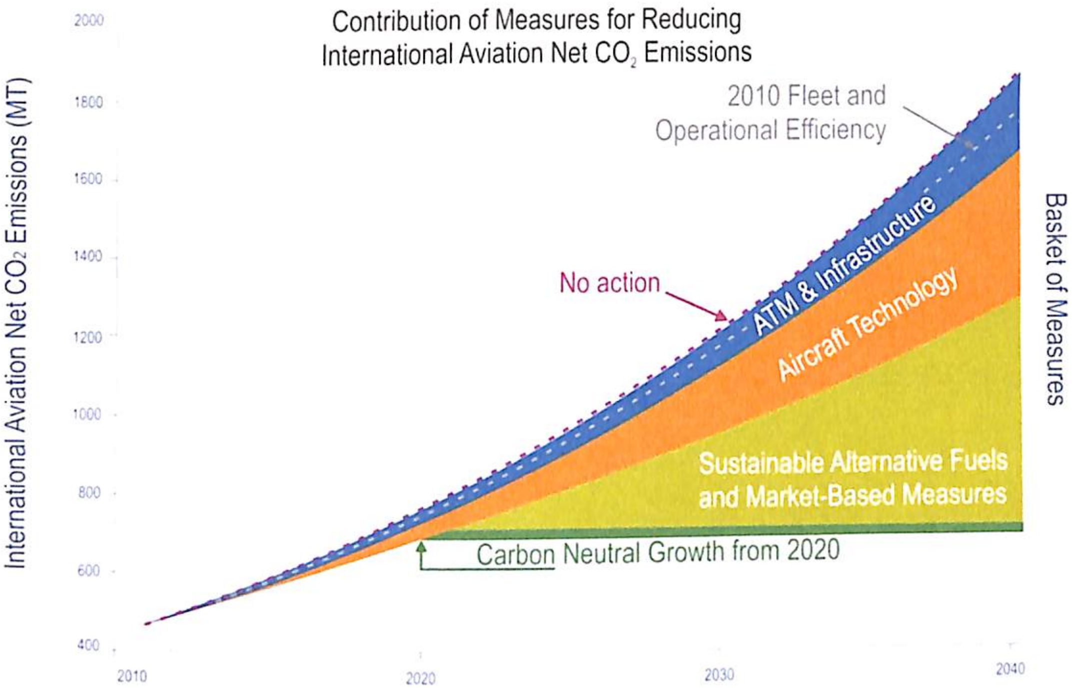
Fast-track Certification of Fuels from Forest Residues

The certification of biofuel production from forest resi- dues will be facilitated by a simplified audit process for forest management certified by the Forest Steward- ship Council (FSC). Thanks to a comparative analysis of the RSB and FSC standards, which identified gaps and areas of overlap, FSC-certified operators will be able to receive RSB certification by demonstrating compliance only with those RSB requirements which are not already covered by their FSC certification. The main gaps are greenhouse gas calculation and food security. Similar comparative studies are nearing completion for the Bonsuccro standard and the Inter- national Finance Corporation (IFC) Sustainability Framework Performance Standards.

Limiting or reducing aviation greenhouse gas (GHG) emissions is a key objective of ICAO's environmental protection activities. In this regard, in 2010, at the 37th Session of the ICAO

Assembly, ICAO's Member States adopted the global aspirational goal to stabilize the international civil aviation GHG emissions at their level of 2020.

The trends assessment performed by the ICAO Committee on Aviation Environmental Protection (CAEP) forecasts that, even with the anticipated gain in efficiency from technological and operational measures, aviation CO_2 emissions will increase in the next decades due to a continuous growth in air traffic (figure below).



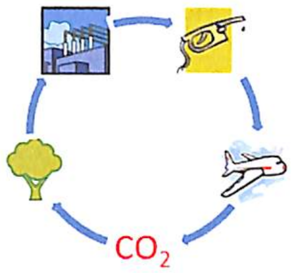
CAEP environmental trends assessment to 2040

Therefore additional measures must be taken into consideration in order to achieve a carbon neutral growth from 2020, including the use of sustainable alternative fuels that have a reduced carbon foot print compared to conventional jet fuel.

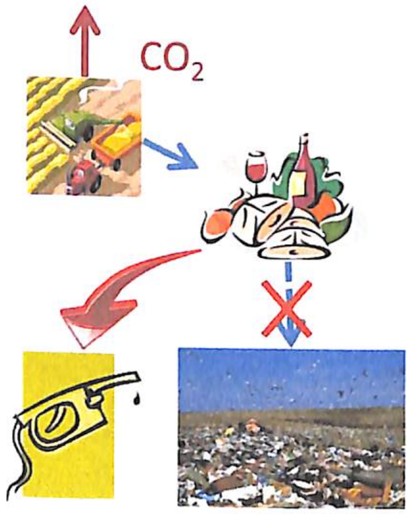
Emissions reductions accrued from the use of sustainable alternative fuels are not as a result of decreased fuel consumption, but through a reduction of the emissions generated by the use of the fuel itself.

Drop-in fuels are synthetic fuels that are designed in such a way that their components and properties are close to those of conventional jet fuels. Hence, they are still hydrocarbons and their combustion still emits CO_2 in quantities similar to those emitted by fossil jet fuel.

To understand how such fuels can generate emissions reductions, two different situations should be considered depending on the type of raw materials that are used.



A first family of alternative fuels consists of biofuels made from various kinds of biomass (crops, wood, agricultural residues, etc.). In that case, the carbon contained in the fuel comes from plants and was uptaken from the atmosphere by plants' growth through photosynthesis. This carbon is emitted back into the atmosphere during the combustion and will return to plants in a close loop. This is not additional carbon injected into the biosphere as it would be the case for fossil fuels. Thus, in the case of biofuels, the emitted carbon can be considered as neutral and combustion emissions can be accounted as zero emissions. This is the source of emissions reductions with biofuels.



A second family of alternative fuels consists of those fuels produced from different categories of waste, such as municipal solid waste or industrial waste gases. These wastes can contain or be made of fossil carbon. In this case, the mechanism for emissions savings is not the neutrality of carbon emissions, but the multiple uses of fossil carbon. Indeed, waste is discarded end-life products from valuable goods (e.g. municipal solid wastes) or by-products with no utilization value from the manufacturing of goods (e.g. industrial waste gas from steel industry). GHG emissions of waste are primarily associated with the production of these goods. Using waste does not add emissions to the system and is thus, carbon neutral. Using a different approach that would consider the value of the fuel produced from wastes, emissions could be shared between the manufacturing of the primary goods and the fuel. Then the fuel would not be zero emissions but, globally, for the same quantity of goods produced (main goods + fuel), an emissions reduction would be achieved.

Competing Uses for Alternative Fuels

A complicating factor in the consideration of alternative jet fuels is that aviation would compete with ground transportation for fuel itself or the feed stocks used to produce that fuel. Because they have similar properties, a fuel that is a suitable substitute for kerosene-type jet fuel is also a potentially suitable substitute for diesel fuel. In fact, the U.S. military uses a jet fuel, jet propellant 8 (JP-8), to power both turbine and diesel engines. The analysis in the following chapters explores the relative attractiveness of potential alternative fuels to competing end-use transportation sectors. The analysis does not consider the broader issue that using potentially scarce biofuels to produce heat and electricity and using the displaced petroleum for transportation may be more effective, from perspectives of energy efficiency and CO2 mitigation, than using biofuels directly in transportation applications (see, for example Hedegaard, Thyø , and Wenzel, 2008). By considering the benefits of using alternative fuels in aviation or ground transportation, one can understand how different applications provide more or less public benefit. This issue is especially relevant for the next few decades, since the amount of renewable resources that can be used to produce liquid fuels will be limited and conventional petroleum will most likely be the primary source of transportation fuels.
High fuel prices and the environmental effects of aviation are motivating strong interest in alternative jet fuels. In the first months of 2008, prices for jet fuel were at record levels
And concerns regarding the environmental effects of aviation on air quality and global climate change were strong. Since 2006, the Commercial Aviation Alternative Fuels Initiative (CAAFI) has brought together the government, industry, academia, and nonprofits to investigate and promote alternative aviation fuels. To date, CAAFI has held two major conferences and has facilitated tests of possible alternative jet fuels. As a result of
CAAFI's efforts, new specifications for jet fuels are being drafted that may enable the commercial introduction of alternative jet fuels. A forthcoming study investigates ten potential alternative jet fuels (alternatives in terms of both feedstock and fuel composition are considered). Within the next decade, the production potential of alternative jet fuels without policy incentives is on the order of ten percent of expected consumption. The emissions of particulate matter and precursors that affect air quality are significantly lower for many of the fuels considered in the study. The life-cycle carbon dioxide emissions of the alternatives range from roughly zero to many multiples of conventional fuel. This range depends on the feedstock, the conversion technology, the availability of opportunities for geologic carbon capture and sequestration, and any indirect land use changes that result from the creation of the bio-

mass feedstock. Lastly, ultra-low sulphur jet fuel can provide an immediate means for reducing emissions that degrade air quality while also paving the way for future alternative jet fuels.

Legal and Regulatory Considerations

FAA and Associated Airport Regulations

There is a significant number of FAA and other regulations that influence the way airports operate and how infrastructure is developed. These regulations can be very site specific and are further influenced by local regulatory bodies. A full discussion of these rules and regulations is outside of the scope of this guidebook; however, Section 6 is devoted entirely to criteria for locating alternative fuel distribution programs on an airport site. That section presents and discusses the major considerations from an airport planning and regulatory perspective that should be taken into account when evaluating these programs.

Regulatory and Policy Framework on Alternative Jet Fuels

The regulatory and policy framework for alternative jet fuels is very dynamic and evolves continuously as the industry itself grows and develops. The federal government as well as state and local entities has several programs to promote alternative jet fuels. These programs include collaboration between the U.S. Navy and the USDA and DOE to invest up to $510 million over 3 years in partnership with the private sector to support production of alternative jet and marine fuels (White House 2011). A recent ACRP publication (Miller et al. 2011) describes in more detail many of the regulations, policies, and other incentives in the United States supporting the development of alternative jet fuels. Other recommended sources for the latest information about alternative jet fuels were listed in Section 1.7.

Regulatory and Policy Framework on Other Alternative Fuels

The regulatory and policy framework for other alternative fuels is complex, because many regulations and policies are fuel specific and vary from state to state. For example, as of November 2011, there were 34 federal and 426 state incentives and laws for ethanol and 37 federal and 434 state incentives and laws for biodiesel.

What Roles Do Airports Already Play in Fuel Distribution?

Airports are currently involved in the distribution and sourcing of conventional fuel. In the case of jet fuel, airports ensure that safety and regulatory requirements of fuel handling and storage are met but are not typically involved with commercial aspects of jet fuel sourcing. The supply of jet fuel at airports is typically the responsibility of airlines that enter into contracts with oil companies, third-party suppliers, or fixed-based operators (FBOs). Furthermore, the jet fuel infrastructure at airports is typically managed and maintained by third-party vendors on behalf of the airports or the airlines. Thus, the sourcing and handling of jet fuel is not usually part of an airport's core business.

With respect to alternative fuels for surface use, there are many different ways in which airports are involved. In some cases, just as with jet fuel, third parties manage refuelling stations and the fuel distribution facilities. In other cases, the airports themselves have facilities and staff with direct responsibility for sourcing and managing some or all of the fuel.

2.2 REVIEW AREA NARROW

Since the energy crisis of the 1970s, almost all of the energy, aircraft, and engine companies, as well as government entities, have been investigating the practicality of using alternative fuels in aircraft, albeit at a relatively slow pace. Because of price and environmental pressures, interest in alternative jet fuels derived from nonpetroleum sources is once again growing. Alternative fuels, if available in sufficient quantities, offer the potential to reduce price, mitigate the effects of supply disruptions, and reduce the environmental impacts of aviation.

More specifically, government, industry, academia, and non-profits are working through CAAFI to pursue alternative jet fuels for the purpose of:

- Securing a stable fuel supply.
- Furthering research and analysis.
- Quantifying the ability to reduce environmental impacts.
- Improving aircraft operations.

CAAFI adopted three high level goals:

- Develop the means to quantitatively differentiate alternative fuels on aircraft platforms.
- Develop methods to quantitatively differentiate alternative fuels at airports on both an environmental and economic basis.
- Establish a secure web based means of communication within the enterprise.

Motivations for Alternative Jet Fuel Use

At the moment, the largest single driver for development and adoption of alternative fuels is the high cost of petroleum combined with aviation's total dependence on petroleum-based fuel. In addition to concerns about rising fuel costs, the possibility of disruptions in petroleum supplies, such as those experienced in the wake of Hurricane Katrina, and the environmental impacts of aviation on climate and air quality are also powerful drivers.

Technical and market considerations

The significant public and political pressures faced by aviation to reduce its impact on the environment are a strong driver behind the active pursuit of alternative jet fuels. As an example, global climate change has been cited as a reason for rejecting multiple airport expansion projects in airports near London, UK. However, most if not all alternative fuels, regardless of feedstock, could be used by ground transportation in either pure form or as a blending stock with conventional petroleum based fuels. Similarly, the same biomass feedstock could be used to generate electricity, heat, fuels for ground transportation, or fuels for aviation.

Ground transport fuel consumption is considerably larger than aviation fuel consumption and the ground transport sector has considerable experience in alternative fuel use (e.g., ethanol, biodiesel, and liquefied natural gas). Because aircraft must carry their fuel aloft, the requirements for aviation fuels are more stringent than those for fuels used for surface transportation. In certain circumstances and because of fuel properties such as octane and cetane number, ground-based vehicles may serve as a more appropriate application of alternative fuels and feedstock resources. Because of the large global aviation fleet designed to operate on a petroleum-based kerosene-type fuel and the existing supporting infrastructure, much attention has been focused on the development of a "drop in" fuel (one that is functionally equivalent to current jet fuel). It is unwise to underestimate the technical difficulties that may be encountered even with "drop in" fuels. Slight differences in fuel composition can have a cumulative effect on operations over time, and there is a constant need to ensure the safety of operations. Production cost and production potential of the alternative fuel are also key considerations.

Current high petroleum prices are motivating interest in alternative jet fuels, but the potential for a price drop combined with the expected dominant position of conventional jet fuel.

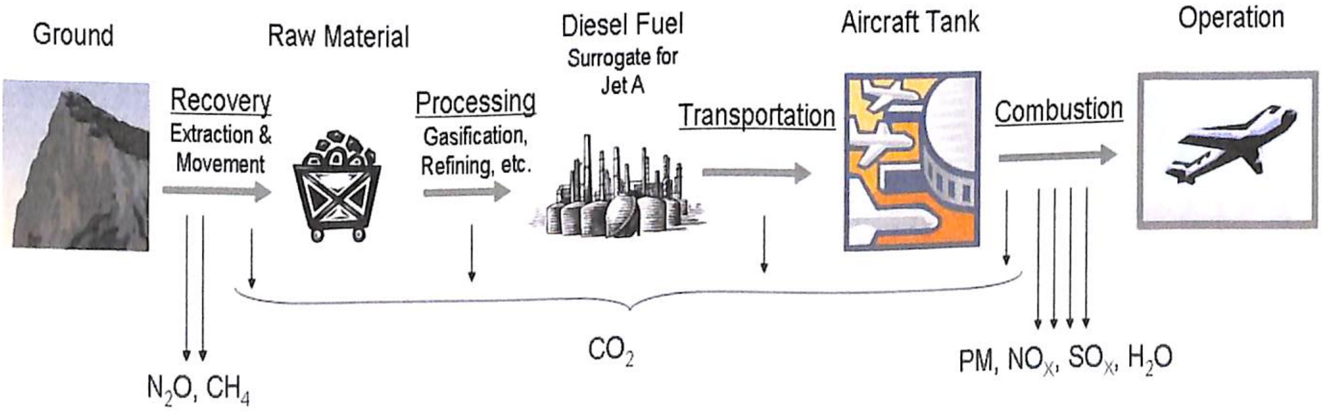


Figure 6: Schematic representation of a well-to-wake life-cycle analyses methodology.

Potential User Groups and Their Motivations

Potential users can be divided into two groups depending on their use of alternative jet fuel or other alternative fuels.

Potential Users of Alternative Jet Fuel

This group includes users of conventional jet fuel such as passenger and cargo airlines and military aircraft. The aviation community has indicated their support and interest in using alternative jet fuels as a means to diversify the jet fuel pool, ensure reliability of supply, enhance energy security, and provide potential environmental benefits (ATA 2010).

Potential Users of Other Alternative Fuels

The following list identifies the key potential user groups for alternative fuels and their motivations:

- **Airport operators**:

Airports of all sizes have their own fleets of vehicles that operate on a variety of fuels, mainly gasoline and diesel. These are clear candidates for using drop-in alternative fuels, such as green diesel or biodiesel. Airports could also be encouraged to use other alternative fuels that may require dedicated fleets, such as CNG or E85, with potential funding from state or federal programs such as the Voluntary Airport Low Emissions (VALE) program (FAA 2011c). Further motivations for airports' introducing alternative fuels include community outreach programs, energy purchasing contracts, and turning waste streams into energy.

- **Airport tenants**:

Airlines, ground service providers, rental car facilities, and other concessions operate significant amounts of vehicles. These operators can be encouraged to use alternative fuels via, for example, joint purchasing with airport GSE through a VALE grant. Alternative fuels can also be encouraged by variable charging structures for licenses to operate airside premises and services. In addition, joint energy purchasing contracts could help reduce energy costs and, at the same time, encourage use of alternative fuels.

- **Bus and shuttle operators**:

These operators could be encouraged to use alternative fuels through preferential treatment by the airport. This preferential treatment could include allocation of bus and shuttle stops closer to terminal building exits and lower charges for operating airport services and parking. These incentives could be enough for adoption of drop-in fuels, such as green diesel or biodiesel, which would require little to no modification to vehicles. For conversion to other types of alternative fuels that would require investment in dedicated vehicles, such as CNG or electricity, further incentives from the airport and local and federal programs may be required. Airports can work with operators to encourage more alternatively fuelled vehicles when vehicle replacement is an option.

- **Taxi and limousine operators**:

Similar to buses and shuttles, taxis and limousines could be encouraged to use alternative fuels by the airport granting preferential vehicle treatment. This could include, for example, preferential allocation of taxi passengers by airport staff at terminal building exits and lower charges for operating at airport and related parking charges. Similarly, airports can work with taxi fleet operators to encourage more alternatively fueled vehicles, including switching to other fuels such as CNG or electricity, when vehicle replacement is an option.

- **Trains**:

As trains tend to operate over a fixed route and be fueled at a central depot, it is more feasible that airport operators work with county and state partners to encourage wider uptake of alternative fuels. These are likely to be limited to drop-in fuels in most cases. However, there is the possibility that new or even existing rail lines to an airport could be electrified, such as via an airport development project, and agreements in terms of supplying electricity from an alternative fuel facility put in place.

- **Cargo truck operators**:

Truck fleets based at the airport, such as those servicing air cargo or package delivery operations, are a potentially significant source of demand for alternative fuels. These operators may be interested in supporting and benefitting from alternative fuel refueling options onsite. Truck operators not based at the airport may be harder to influence, although incentives such as preferential buying from suppliers who use alternative fuel trucks may act as a form of motivation.

- **Private vehicle operators**:

Private vehicles constitute a large percentage of the traffic to and from U.S. airports, representing a significant potential demand for alternative fuels. It is unlikely that airports acting alone could encourage public car drivers to change their vehicles to ones running on alternative fuels. However, in collaboration with county and state partnerships, it is possible that a larger proportion of the public could be encouraged to drive alternatively fuelled vehicles, such as by increasing fuel options at gas stations and other mechanisms. Airports could play a role by providing refueling options for alternative fuels, for example, charging bays for electric vehicles and CNG dispensers, and incentives such as variable parking lot charges and dedicated spaces closer to terminal buildings.

- **Water transportation (ocean or freshwater)**:

Ferries and small passenger boats generally use gasoline or diesel engines comparable to those in automobiles and so are ideal candidates to utilize alternative fuels. In an airport setting, joint purchases of biodiesel and green diesel could lower costs and increase efficiency by utilizing economies of scale inherent in purchase agreements. However, it is exceedingly rare that an airport utilizes ferries or boats as a primary method of public transportation to and from the facility. In fact, Boston Logan International Airport is unique among major U.S. airports in offering scheduled ferry service from the airport to destinations in downtown Boston. As maritime modes are not a normal part of the mix of surface transportation options at most airports, they are not a focus of this report.

- **Off-airport users**:

The unique role that the airport plays within a community offers an opportunity for the airport itself to take a lead role in the provision of alternative fuels for airport operations as well as for off-airport operations undertaken by the general public. Given their physical characteristics, airports can use alternative fuels to expand their businesses. Storing and distributing drop-in alternative fuels requires no significant new investment in infrastructure on the airport's part, which lessens the cost of providing the fuel to the community. Most new investment would be focused on expansion of facilities and infrastructure, the cost of which could be borne by a combination of user groups. Alternatively, if airports do not wish to directly manage fuel storage and delivery of alternative fuels, they could lease land out to a third party and still have the potential to capture value.

New Partnerships

KLM believes that cooperation is key for the future of sustainable biofuel in the aviation industry, in order to make a real impact on lowering the environmental footprint.

In June 2012, KLM launched the world's first corporate bioFuel programmed for contracted corporate accounts. This allows the staff of the contracted companies to fly a part of their company travel or their travel on specific routes on sustainable biofuel. The programmed aims to stimulate the further development and production of biofuels and as such reduces the aviation industry's carbon footprint. In one year, the number of programmed partners has more than doubled to fifteen. KLM's BioFuel Programme now includes the City of Amsterdam, Loyens & Loeff, PGGM, FMO, Delta Air Lines, Siemens, TomTom and CBRE Global Investors. They followed initial customers including Ahold, Accenture, DSM, Heineken, Nike, Philips and Schiphol Group who have been supporting KLM's BioFuel programmed from the very beginning.

In 2013 KLM, Schiphol Group, Delta Air Lines, and the Port Authority of New York initiated a joint project and expanded cooperation resulting in the series of flights from New York with sustainable biofuel.

Figure 7: KLM'S Bio fules programmer partners

The JFK Series

This first intercontinental series of biofuel flights from New York to Amsterdam again proves KLM's pioneering role in the development of sustainable biofuel. 8 March 2013 marked the start of the 26-week series of flights from JFK. This also provided the Port Authorities of JFK to gain expertise on the logistics and regulations regarding the use of biofuel, thus creating a dual biofuel port next to Schiphol.

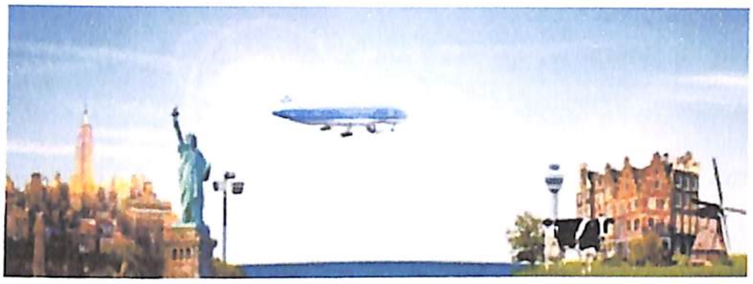
The sustainable jet fuel used for the weekly flights on B777-200 aircraft was 100% US-based fuel made from used cooking oil (UCO) and camelina oil sourced

and supplied by SkyNRG. SkyNRG is the first fully

renewable jet fuel supply chain certified by RSB and is partly founded by KLM. RSB has set the world's highest standards that respect people and the environment when producing biofuel. KLM and SkyNRG have introduced a variety of measures to guarantee and monitor the supply chain's sustainability, SkyNRG has installed an independent Sustainability Board consisting of leading NGOs and scientists who provide advice about feedstock and technology decisions.

Figure 8: partners of KLM'S bio fuels program me

The lifecycle greenhouse gas emission reduction from pure bio-derived aviation fuel varies depending on extraction and processing arrangements, as well as on the type of feedstock used. In general sustainable jet fuels made from UCO can provide a reduction in overall CO_2 lifecycle emissions up to 80% compared to fossil fuels; for sustainable jet fuels made from camelina, this is currently 70%. These figures include the emissions from the production of the fuel, such as transportation and refining.



Dutch partners for
more sustainable aviation
and nature conservation

KLM

WWF

SkyNRG

After enabling many of the first commercial bio jet fuel initiatives in 2011 and 2012, the launch of innovative co-funding mechanisms (e.g. SkyNRG's Corporate Program) in 2012 and scaling up to structural green routes in 2013 (e.g. KLM's green route to JFK) SkyNRGis looking to the future. To take this market to the next level the industry recognizes the need for dedicated bio jet fuel production capacity. SkyNRG's efforts will be directed towards achieving this. The SkyNRG Bioport proposition and the Corporate Program will play an important role in this.

In the last year SkyNRG has started to roll out its Corporate Program beyond KLM, with selected airlines around the world. SkyNRG expects the program to be fully active during the first half of 2014.

SkyNRG

Figure 9: skyNRG

During 2013 SkyNRG invested in its Bioport proposition, which essentially creates a demand centre at the end of the supply chain (airport/airline combination) and from there helps to structure a regional bio jet fuel supply chain. A regional effort, in which the airline plays an instrumental role in enabling the supply chain, has multiple benefits including significant GHG reductions. For example, it reduces price volatility, helps improve regional energy security, brings social economic development to (rural) areas, stimulates innovation and research & development, and creates a basis for new industries to grow or existing industries to diversify. Furthermore it engages a wide range of (local) stakeholders as well; government, farmers, industry, investors, knowledge institutes, NGOs etc.

A first tangible result of this strategy was announced in April 2013, when SkyNRG launched its first Bioport with Virgin Australia and Brisbane Airport Corpora-tion[34]. The partnership expects to have a commercial scale, regional bio jet fuel supply chain up and running before 2020.

Airbus's renewable fuel activities

Airbus's sustainable aviation fuel strategy is focused around three central principles; to support the qualification and certification of new aviation fuels, to support the large scale use of sustainable aviation fuels and to target the sustainability of the solutions.

International partnerships and research projects

Airbus's strategy is managed around the world through partnerships and research projects. 2013 saw the launch of an initiative with BioFuelNet Canada and Air Canada to assess the solutions in Canada for the production of sustainable aviation fuels for the Canadian aviation market. This partnership followed the Perfect Flight completed by Airbus and Air Canada in 2012, bringing together all best practices including operational, maintenance, air traffic management and the use of sustainable fuels to achieve an over 40% reduction in CO_2 emissions on a commercial flight from Toronto to Mexico City. The collaboration between Airbus and Air Canada was rewarded with the 2013 Eco-Partnership Award given by Air Transport World.

Airbus also came together in 2013 with Air France, Total and CFM to perform a demonstration flight at Le Bourget Air Show using an Airbus A321 with fuel efficient sharklets and BioJet A-1 biofuel from Total/ Amyris produced through an innovative conversion of sugar.

Further collaborations launched in 2013 included a cooperation agreement between Airbus and Rostec group in Russia to launch a large-scale analysis of Russian feedstock and to evaluate how to speed up the development and commercialization of sustainable fuels in the region.

Airbus believes a key element of the development of sustainable fuels for aviation is political support and frameworks to ensure optimization, financial investment and sustainability. In this spirit, Airbus works closely with the EU commission through ITAKA (Initiative Towards sustAinable kerosene for Aviation). This collaborative project is framed in the implementation of the European Union policies specifically and aims to contribute to the short-term (2015) EU Flight Path objectives. The ITAKA project is expected to support the development of aviation biofuels in an economically, socially and environmentally sustainable manner, improving the readiness of existing technology and infrastructures (see Section 5.4.1 for further details on ITAKA).

In addition to ITAKA, Airbus participates in SAFUG (Sustainable Aviation Fuel Users' Group) in the USA, SA (Sustainable Aviation) in the UK, and NISA (Nordic Initiative for Sustainable Aviation) in Northern Europe.

Initiatives launched over recent years are now beginning to come to fruition. In 2012, Airbus launched its collaboration with Tsinghua University in China to complete a sustainability analysis of Chinese feedstocks and to evaluate how best to support the development of a Chinese value chain to speed up the commercialization of sustainable aviation fuels. This value chain aims to produce and promote the use of sustainable aviation fuel in China, the world's fastest growing aviation market. The first report from this collaboration has been successfully delivered allowing Airbus and Tsinghua to move forward in the next step of this collaboration.

Airbus believes it is necessary to have both a long-term vision and short-term strategic actions to ensure the development of sustainable fuels for aviation. The achievements in 2013 will allow Airbus to prepare for 2014 and beyond to face the challenge of ensuring large scale use of sustainable fuels in the future.

Figure 10: Air Canada's 'Perfect Flight' fueling opera-

Boeing's renewable fuel activities

Asia Pacific

Boeing sponsored and provided significant content to an Association of South East Asian Nations (ASEAN)-hosted aviation biofuel workshop in Bangkok. This event has generated significant interest in the topic among regional airlines. Additionally, Indonesia's government announced the world's first mandated use of biofuel for aviation with a 2% target by 2015 and 3% by 2018. In Singapore, Singapore Airlines and the Civil Aviation Authority of Singapore have awarded a contract to SkyNRG and Climate Solutions to conduct a biofuel supply feasibility study for the island nation.

Latin America

Brazil's Aviation Biofuel Platform was launched with Boeing and many other parties, as a follow on from the Flight Path for Aviation Biofuels in Brazil (FABB) road mapping process. The platform, led by GOL, will drive commercialization of aviation biofuel supply chains in Brazil. Notably, on Oct 23, GOL flew first Brazilian commercial biofuel flight from Sao Paulo to Brasilia on a 737-800. Progress has been facilitated by the Brazilian National Agency for Petroleum, Natural Gas, and Biofuels (ANP), who approved a hydroprocessed esters and fatty acids (HEFA) pathway for commercial jet fuel.

Europe

Boeing participates on the steering board of the recently launched Nordic Initiative for Sustainable Aviation (see Section 6.4 above). Via the Sustainable Aviation Fuel Users Group (SAFUG), Boeing and certain airlines engaged European Parliament in their recent contemplation of indirect land use change (ILUC). A new rule includes an amendment that incentivizes oil companies to supply jet fuel containing biofuels, which would encourage production of aviation biofuels.

Middle East and Africa

South African Airways and their parent Department of Public Enterprises signed an MOU for collaboration with Boeing on biofuels, becoming the first airline in Africa to formalize an effort on this topic. The Sustainable Bioenergy Research Consortium (SBRC), founded by Etihad Airways, Boeing, Honeywell-UOP, Masdar Institute of Science and Technology, and SAFRAN is midway through its development of the Integrated Seawater Energy and Agriculture System (ISEAS) which utilizes salt tolerant biomass and aqua-culture waste to produce both fuel and food from arid lands.

North America

Together with United Airlines, Boeing and many other stakeholders completed the Midwest Aviation Sustainable Biofuels Initiative (MASBI - see Section 6.2 above), which is a multi-stakeholder aviation biofuel roadmap process focusing on the viability of sustainable aviation biofuels production in Midwest of the United States. Also, Boeing sponsored and participated in the Algal Biomass Summit in Orlando, FL. Steady progress on deploying algae for fuel, feed, food, and higher value markets was on show to over 650 participants from around the world.

Figure 11: The life cycle of bio fuel production

2.3 FACTORS CRITICAL TO SUCCESS OF STUDY

- Achievement of results
- Satisfaction from project results
- Sustainable positive effects
- Execution of project activities
- Skilled resources
- Project management expertise
- User involvement
- Proper knowledge about the subject
- Various ideas about the books
- Manage the project scope effectively
- Cultivate constant effective communication
- Agree on the project goals
- Make sure you have management support
- Develop clearly defined plans with assigned responsibilities and accountabilities

2.4 SUMMARY

Alternative jet fuels for aviation are an area of great interest and ongoing research because of their potential to ease jet fuel price pressures and their potential to reduce aviation's impact on both air quality and global climate change. Since 2006, the FAA, DoD and the aviation and fuels industries (along with other stakeholders) have aligned their efforts to explore the potential of alternative jet fuels through the Commercial Aviation Alternative Fuels certification goals.

The rising cost of oil coupled with the need to reduce pollution and dependence on foreign suppliers has spurred great interest and activity in developing alternative aviation fuels.

Although a variety of fuels have been produced that have similar properties to standard Jet A, detailed studies are required to ascertain the exact impacts of the fuels on engine operation and exhaust composition.

High fuel prices and the environmental effects of aviation are motivating strong interest in alternative jet fuels. In the first months of 2008, prices for jet fuel were at record levels and concerns regarding the environmental effects of aviation on air quality and global climate change were strong. Since 2006, the Commercial Aviation Alternative Fuels.

Initiative (CAAFI) has brought together the government, industry, academia, and nonprofits to investigate and promote alternative aviation fuels. To date, CAAFI has held two major conferences and has facilitated tests of possible alternative jet fuels. As a result of

CAAFI's efforts, new specifications for jet fuels are being drafted that may enable the commercial introduction of alternative jet fuels. A forthcoming study investigates ten potential alternative jet fuels (alternatives in terms of both feedstock and fuel composition are considered). Within the next decade, the production potential of alternative jet fuels without policy incentives is on the order of ten percent of expected consumption. The emissions of particulate matter and precursors that affect air quality are significantly lower for many of the fuels considered in the study. The life-cycle carbon dioxide emissions of the alternatives range from roughly zero to many multiples of conventional fuel. This range depends on the feedstock, the conversion technology, the availability of opportunities for geologic carbon capture and sequestration, and any indirect land use changes that result from the creation of the biomass feedstock. Lastly, ultra-low sulfur jet fuel can provide an immediate means for reducing emissions that degrade air quality while also paving the way for future alternative jet fuels.

CHAPTER 3: RESEARCH DESIGN, METHODOLOGY AND PLAN

3.1 DATA SOURCES

There are two types of data. Primary data and secondary data. For this research I used secondary data. Secondary Sources constituted the whole of research work. There are two distinctive sources of secondary data.

1. Internal
2. External sources.

Some of the external sources are:-

- Directories
- Published marketing research reports
- News sources
- Internet
- Books and journals
- Research reports
- Magazines and articles

3.2 RESEARCH DESIGN

The purpose of the systematic literature review was to gather up to date, reliable and relevant information about all aspects of bio jet fuels, their production, use, availability, safety factors, cost and sustainability. Therefore, the literature review method selected was the narrative review which is interpretative-qualitative in nature (Rumrill & Fitzgerald, 2001). The review was used to:

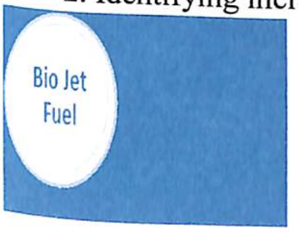
1. Identifying studies of sufficient authority and quality to form the basis of the literary review
2. describing the current state of use for traditional and bio fuels in the aviation industry and outline and discuss the features of bio fuels, both positive and negative identified in the studies
3. Add dimensions of insights or application that are not available in existing literature
4. Provide critical analysis of all the information

There were limitations to this type of literature review such as being more subjective than some other forms of review (Rumrill & Fitzgerald, 2001). However, this method was still appropriate and robust enough for this project.

METHODS

In finding literature to review, the first steps were:

1. Identifying the appropriate literature that related to the question and;
2. Identifying inclusion variables



- Availability and usage
- Sustainability and Growth
- Fuel price
- Safety factors

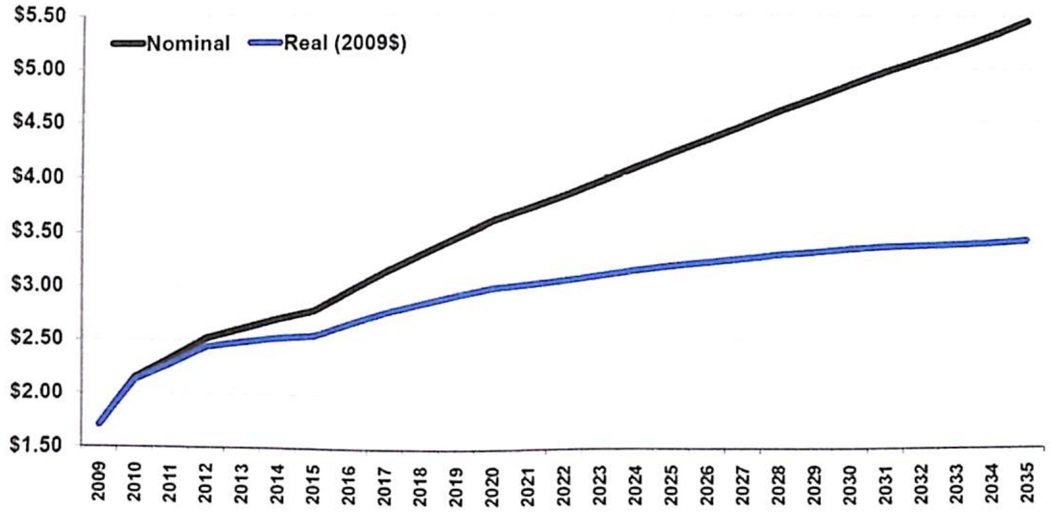
This was done by finding relevant literature using Google scholar or Uni SA library search modules and typing in key words; bio jet fuel, fuel prices, sustainability and availability, usage, costs of bio jet fuel, safety factors, Airbus, Green air articles, IATA, ICAO. These search modules provided reliable and up to date literature.

The next steps were to:

3. Study the data for each variables and;
4. Drawing conclusions about each.

Excel was used to conduct the statistical analysis of each variable and the results led to suggestions on which fuel type would be more beneficial in aircraft operations in the future.

3.3 DATA ANALYSIS PROCEDURES



Can Alternative Jet Fuel Be Price Competitive?

Projected Average US Price Per Gallon of Traditional Jet Fuel

Source: Energy Information Administration, including Short-Term Energy Outlook (Jan. 11, 2011) forecast of "Jet Fuel Refiner Price to End Users

The recent dramatic rise and volatility in fuel prices has caused intense concern in the aviation industry and is driving significant fleet restructuring. The current price of jet fuel is approximately four times what it was just four years ago. This unprecedented escalation has created a fundamental shift in the economics of air travel in which gains in other areas of the airline industry are being negated by increases in fuel costs. As long as jet fuel that is derived from conventional petroleum remains the dominant fuel, the price of petroleum will define the market price for jet fuel. However, alternative fuels offer the potential for a shift away from a petroleum dominated market.

Cost challenges for several biojet pathways have been examined, and price premiums have been found to originate from different sources depending on the fuel pathway. Incentive structures and technological improvements can reduce these cost burdens. As a result, aviation biofuels may have the potential to become cost competitive with conventional jet fuel in the near future. Another significant avenue for cost reduction is the possibility of producing high value chemicals along with jet fuel. This can be achieved via different biochemical and thermo chemical routes. For example, aqueous phase processing of lingo cellulosic feedstocks can produce furfural, hydro xymethylfurfural (HMF), and acetic acid in addition to fuel products. These high value chemicals can be sold at market prices to internally subsidize the cost of the biofuels. Ongoing research at MIT on this pathway indicates that having biofuels as a by-product of chemical production has been shown to reduce the MSP of the biofuel by 77% compared to a case in which the bio refinery is set up to maximize fuel output. This would make the fuel cost competitive with conventional jet fuel, with or without RINs. However, limitations in terms of the size of the chemical markets need to be taken into account, since flooding of these markets with renewable products will drive the price down, therefore reducing the value of the non-fuel part of the refinery output and driving up the required selling price of renewable jet fuel. Therefore, the bigger the market for the renewable chemicals being produced, the smaller the price effect of additional production and consequently, the bigger the benefit from co-producing fuels and chemicals.

Competitive markets should lead to selling prices decreasing over time. This is especially the case for new technologies where significant cost reductions can be achieved through learning. Among the alternative fuel technologies considered herein, FT is the most mature, having been used for decades with coal (Sasol) and for several years with natural gas (Shell).

Biomass gasification is largely based on mature coal gasification technology, but additional bio mass specific treatment methods are less mature. Learning effects can be significant, especially in the early years of technology deployment. In a study conducted for the U.S. Department of Energy, for example, it was estimated that costs for HDC-D should decrease by ~50% over the course of five years due to improvement in achieved process efficiencies.

Theoretical purchase prices for mature industries have been calculated in literature using minimum selling price (MSP) approaches. These prices are meant to be representative for fuels which are produced in several refineries using a certain technology, with lower contingency, start-up costs and risk premiums than first of its kind plants. These "N-th plant" studies rely on techno economic analyses to estimate capital expenses and operating costs for fuel production facilities. Plant economics can be assessed by employing a discounted cash flow rate of return (DCFROR) model, which is standard practice for chemical engineering cost analysis. These models capture the net present value of discounted cash flows related to loan interest payments, direct and variable operating costs, sales revenues, and taxes. Other financial parameters are included as necessary, such as construction time, production ramp up, depreciation, and inflation to model various production scenarios. The minimum selling price is determined from this information and represents the price at which the fuel must be sold in order for the project to achieve a specified internal rate of return (with a net present value of zero). If multiple products are produced, the prices of the co-products are either held constant at market value (isolated cost burden) or varied relative to the jet fuel price (distributedcost burden).

CHAPTER 4: FINDINGS AND ANALYSIS

4.1 FINDINGS & ANALYSIS

Availability and Usage

The literature review suggests that availability is restricted by having limited feedstock accepted for use. Biofuels mixes need to be either Fischer-Tropsch (TP) or hydro processed esters and fatty acids (HEFA) (Davidson, Newes, Schwab & Vimmerstedt, 2014). Only having these two approved bio fuel types limits the availability enormously. ICAO states that currently in Mexico they have plenty of plantations which produce biofuel ingredients such as Jatropha and palm oil. However, these operations are outside the legal framework and are not allowed to be used in aviation (ICAO, 2013). Expanding feedstock is the key component in increasing availability of biofuels in aircraft operations, which in turn would reduce the price. Findings further showed that usage of biofuel is proportional to the availability, because all that is being produced is being used. Figure 3 below shows the availability and usage of both traditional fuel and biofuels from 2000 to 2010.

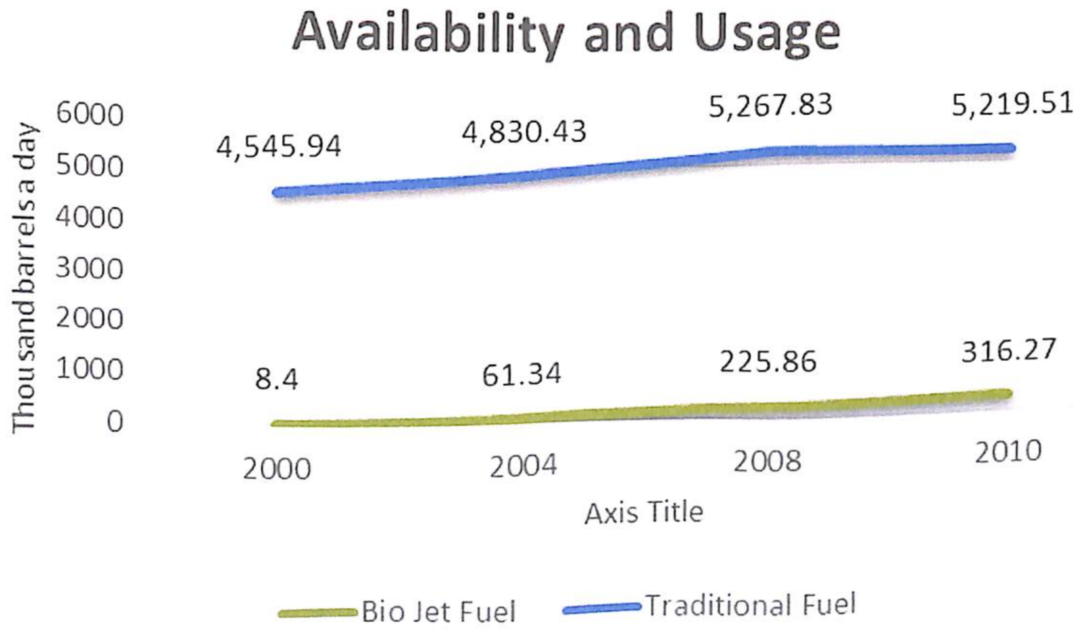


Figure 3. Availability and Usage of Fuels

It can be concluded (Figure 3) that biofuel's availability is increasing slowly and will increase in the future as technology and facilities are improved. Although traditional fuel production has been stabilised at present, indicating there might be a slight decrease in AVTUR price, it is really hard to predict the pricing for the future because air travel is increasing, thus even more fuel is required to satisfy the fuel needs in the aviation industry. It therefore makes sense to ensure biofuels are more price-competitive and suitable for airlines by expanding production and increasing availability. According to a study that was conducted by the United Kingdom Government in 2009, the full replacement of traditional jet fuel would require a total of 231 million hectares of land which represents 16% of arable land (ICAO, 2013).

Sustainability and Growth

Sustainability was found to be the main precondition of all variables that were investigated. There was an unlimited supply of statements from reliable sources indicating that biofuel's challenge is to become sustainable within the aviation industry worldwide. However, multiple problems were identified that effect biofuels growth. It was discovered from the literature that the legal framework and policies are not harmonised worldwide which interfere with the worldwide supply chain program. As KLM's Head of Tactical Planning, Thijs Kommen, comments, "If these hurdles are taken away, the business case will be sounder than it is today" (Greenair Communications, 2014). Further, if the feedstock processing could be made simpler, then biofuels would challenge the traditional fuels in price and competitiveness. At the moment the price of the biofuels is just too great when compared to AVTUR. Figure 4 shows the average prices of AVTUR and biofuel in the past and it can be predicted that traditional fuel prices will keep rising proportionally as they have in the past ten years (Figure 4) due to the higher demand and limited availability of traditional fuels in the future.

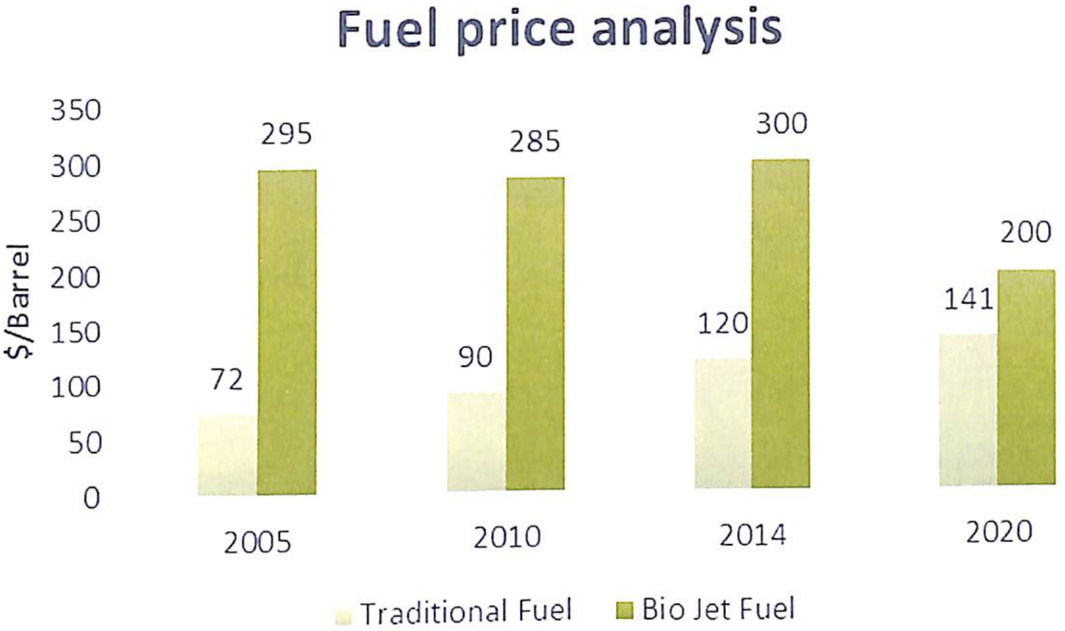
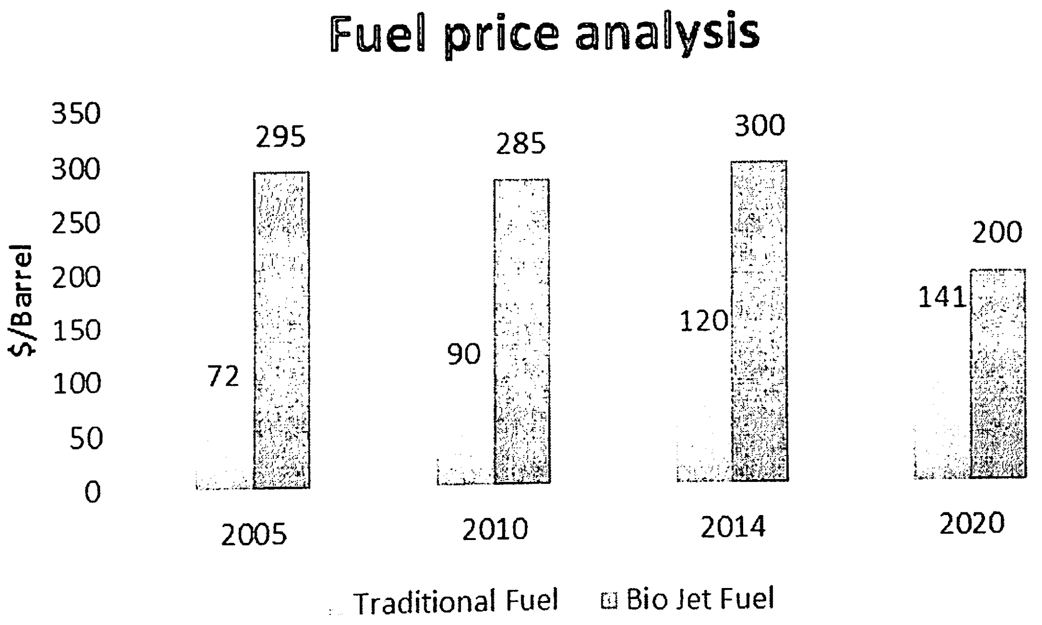


Figure 4. Fuel price analysis

The biofuels price analysis was completed using average data. This is because it was acknowledged that there are a range of different ingredients (Jatropha, palm oil, Algae, corn etc.) from which biofuels can be made and the price difference of production can be huge, thus an average was used. However, of note is the fact that the price did not fluctuate greatly from 2005 to 2014.

Research indicates that third generation biofuels are particularly promising because less space and water is required to produce them , increasing the likelihood that that they could be sustainable (ICAO, 2013) with Rosillo-Calle and Teelucksingh believing that biofuels could become cost competitive in 2020 (2012, p.7). The British Airways' Head of Environment, Jonathon Counsell, points out that supplying just 100 airports worldwide with alternative fuels would deliver around 80% of global airline demand (Greenair Communications, 2014), which would not require broad supply chains worldwide in the near future so could be sustained. This sustainability would reduce the price and close the gap between traditional fuel prices making biofuels a serious competitor against traditional fuels. If a chain worldwide were still an issue, then ICAO and IATA would need to harmonise the legal framework and make it easier to apply for approvals, so the biofuels supply chain would be unbroken worldwide. This information suggests that although there are some issues to be dealt with, biofuels can become a real alternative and offer choice for fuel in aircraft operations from 2020.



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Safety factors

In the literature review experts agreed on the safety benefits when using the newest generation of bio fuels. Findings showed that the safety benefits also attracted positively public's interest towards aviation (ICAO, 2011). It was found that there were no changes required in the engines to use biofuels mixes in aircraft operations (IATA, 2014). In Greenair 's (2014) report, Kaisa Hiatala - part of Neste Oil Company - reported that the 1187 flights that had used bio fuel blends performed normally and overall fuel consumption was 1% lower due to the higher energy content. Further, the engine parts were in the same condition and functioning normally without any corrosion in the fuel tanks (Green air Communications, 2014).

Safety factors will not make a significant impact on cost savings and so do not directly affect the research question. However, safety stakeholders do promote the use of bio fuels to airlines instead of traditional fuel, contributing positively to the growing usage of bio fuels.

4.2 CORRELATION/ REGRESSION ANALYSES

In my project, I use the correlation analysis. It is a statistical technique used for measuring the relationship or interdependence of two or more variable.

Alternative aviation fuels compete with conventional jet fuel from petroleum. Airlines operate in a highly competitive, low-margin market and can be expected to refrain from large-scale usage of alternative fuels if they are not cost-competitive with the conventional counterpart. This does not necessarily imply that these fuels need to be competitive on their own in the short term, since there are policies in place that give incentives to produce and use alternative aviation fuels.

Correlation, a statistical measure of a relationship between two or more variables, gives an indication of how one variable may predict another. The descriptive techniques discussed above permit a statement, in the form of correlations, about that relationship. However, correlation does not imply causation; that is, simply because two events are in some way correlated (related) does not mean that one necessarily causes the other. For example, some test data indicate that boys receive higher math-aptitude scores on college entrance exams than girls, indicating a correlation of gender with mathematical ability. But before concluding that gender **determines** mathematics aptitude, one must demonstrate that both the boys and the girls in the study have had the same mathematics background. Some studies have shown that girls are discouraged from taking or at least not encouraged to take more than the minimum mathematics requirements.

CHAPTER 5: INTERPRETATION OF RESULTS

5.1 INTERPRETATION OF RESULTS

For this research, whatever I found is true. The hypothesis of this research is, to determine whether the long term benefits of alternative fuel outweigh the cost of implementation when compared to the current running costs of traditional jet fuel i.e. AVTUR. Specifically would it be cheaper to use bio jet fuels in aircraft operations instead of AVTUR in the future?

A hypothesis must be verifiable by statistical and analytical means, to allow a verification or falsification. In fact, a hypothesis is never proved, and it is better practice to use the terms 'supported' or 'verified'. This means that the research showed that the evidence supported the hypothesis and further research is built upon that. A research hypothesis, which stands the test of time, eventually becomes a theory, such as Einstein's General Relativity. Even then, as with Newton's Laws, they can still be falsified or adapted.

A scientist who becomes fixated on proving a research hypothesis loses their impartiality and credibility. Statistical tests often uncover trends, but rarely give a clear-cut answer, with other factors often affecting the outcome and influencing the results. Whilst gut instinct and logic tells us that fish stocks are affected by over fishing, it is not necessarily true and the researcher must consider that outcome. Perhaps environmental factors or pollution are causal effects influencing fish stocks. A hypothesis must be testable, taking into account current knowledge and techniques, and be realistic. If the researcher does not have a multi-million dollar budget then there is no point in generating complicated hypotheses.

In the aviation industry, almost half of the operational costs for an Airline come from fuel purchases. To assist operational savings, the industry is so eager to find fuel alternatives such as bio jet fuels for aircraft operations. Previous research has emphasised the positives of bio jet fuel focusing on its being safer and more environmentally friendly. However, in order to reach a well-informed decision, all of the factors including additional positive aspects and the disadvantages of using bio jet fuels must be considered. This research uses a detailed literary review and statistical analysis of a range of variables including availability, usage, growth, fuel prices, safety factors, and sustainability. The literature findings suggest that bio jet fuels needs to grow as an industry and that sustainability is the key to its success. This is supported by the results of analysis of variables. These findings indicate that it is highly likely that bio jet fuels will become a real option to traditional fuels in the aviation industry in the near future As bio jet fuels continue to develop, further analysis is recommended to ensure they are sustainable and that availability and price remain positive in comparison to traditional fuels so that there is a considerable saving in operational costs while ensuring safety is not compromised.

5.2 Comparison of Results with Assumptions (Hypotheses)

The hypothesis of this research is, to determine whether the long term benefits of alternative fuel outweigh the cost of implementation when compared to the current running costs of traditional jet fuel i.e. AVTUR. Specifically would it be cheaper to use bio jet fuels in aircraft operations instead of AVTUR in the future?

Result:

The result I found is In the aviation industry, almost half of the operational costs for an Airline come from fuel purchases. To assist operational savings, the industry is so eager to find fuel alternatives such as bio jet fuels for aircraft operations.

A research hypothesis is the statement created by researchers when they speculate upon the outcome of a research or experiment. Every true experimental design must have this statement at the core of its structure, as the ultimate aim of any experiment. The hypothesis is generated via a number of means, but is usually the result of a process of inductive reasoning where observations lead to the formation of a theory. Scientists then use a large battery of deductive methods to arrive at a hypothesis that is testable, falsifiable and realistic. This is too broad as a statement and is not testable by any reasonable scientific means. It is merely a tentative question arising from literature reviews and intuition. Many people would think that instinct and intuition are unscientific, but many of the greatest scientific leaps were a result of 'hunches'. The research hypothesis is a paring down of the problem into something testable and falsifiable

CHAPTER 6: CONCLUSION AND SCOPE OF FUTURE WORK

CONCLUSION

Although the aviation sector has a good track record in reducing its environmental impact through efficiency gains, it is highly unlikely to reduce or even stabilise its emissions through this means alone. Biofuels present a real potential for reducing GHG emissions, provided the feedstock production step is well mastered, and BTL and HRJ pathways should be available in the short term to produce Biofuels compatible with aviation requirements and current aviation systems.

The aim of this project was to determine if it would be cheaper to use bio jet fuels in aircraft operations instead of AVTUR in the future. Research suggests that the usage of all fuels worldwide is increasing thus there is a need for an alternative fuel. The results of the literature review suggest that with some growth in availability of bio jet fuels and the price stability over the last ten years, bio jet fuels are the best candidate in competing with the traditional fuels in the aviation industry. The huge development in production, safety and reduced emission in bio jet fuels also support this recommendation. However, bio jet fuels are still more expensive than traditional fuels and are restricted to the limited feedstock accepted for usage in today's aircrafts. If the availability and production could be increased this would result in a huge reduction in price and therefore bio jet fuels would be price competitive with traditional fuels. The key to sustaining bio jet fuels in the aviation industry is to expand feed stocks which would increase their availability and reduce the price. As the review indicates, if current work by the industry continues bio jet fuels could be a real alternative by 2020 and would be more beneficial in aircraft operations when compared to AVTUR.

RECOMMENDATIONS

As indicated in the literature, additional research is needed in this field to provide better estimates of the bio jet fuel prices in the future and to confirm if they are decreasing or have risen again. Further study is also necessary into the third generation bio jet fuels that are under development because they are predicted to be the most promising alternative fuels in aviation operations in the future. Lastly, the following recommendations are relevant to this field of study and would improve bio jet fuels development in the future.

- Additional exploration to find new raw feedstock material that is easy to grow in a smaller area with minimal use of water and money.
- Harmonisation of the legal framework and recognition mechanisms worldwide to sustain and increase the availability of bio jet fuels.

- Encouraging organisations to use bio jet fuels and agree to long lasting contracts with biofuel providers and Promotion of programs providing government and private funding.
- Global collaboration so every organisation is required to work together towards sustainability of bio jet fuels in the aviation industry and to make it a real alternative to traditional fuel.
- Construction of more advanced technology facilities to create and investigate third

FUTURE WORK

The benefits and costs of ULS fuels showed significant reductions in health impacts via reductions in both primary and secondary PM emissions. The FAA, in collaboration with CAAFI stakeholders, is sponsoring the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Centre of Excellence to conduct a more in-depth study in coordination with the Coordinating Research Council to assess the benefits and costs of ULSjet fuels. Ultimately, reducing PM is especially important for airports in crowded urban areas that already have poor air quality and alternative jet fuels may provide an attractive solution to mitigate aviation PM impacts. Efforts by PARTNER cosponsored by theFAA and the U.S. Air Force will continue to examine environmental costs and benefits of alternative jet fuels through measurements and modelling. Future plans include refining the lifecycle assessment. Refinements include the development of new baseline estimates for petroleum Jet a (prior analysis used diesel fuel as a proxy for Jet A), addressing uncertainties in feedstock inputs, and the inclusion of the impacts of direct and indirect land use changes, as appropriate.

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