UNIVERSIDAD POLITÉCNICA DE MADRID

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS AERONÁUTICOS

**Investigation on the applicability of biofuels in the
operation of commercial aircraft**

Tesis Doctoral

Hazariah Mohd Noh

Bsc in Aircraft Maintenance Engineering Technology
Msc in Aeronautics Engineering

Madrid, July 2016

**DEPARTAMENTO DE SISTEMAS AEROESPACIALES, TRANSPORTE
AÉREO Y AEROPUERTOS**

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS AERONÁUTICOS

Investigation on the applicability of biofuels in the operation of commercial aircraft

Ph.D. Thesis Dissertation

Hazariah Mohd Noh

Bsc in Aircraft Maintenance Engineering Technology

Msc in Aeronautics Engineering

Director:

Gustavo Alonso Rodrigo

Doctor Ingeniero Aeronáutico

Madrid, July 2016

Tribunal nombrado por el Sr. Rector Magfco. de la Universidad Politécnica de Madrid, el día.....de.....de 20....

Presidente: _____

Vocal: _____

Vocal: _____

Vocal: _____

Secretario: _____

Suplente: _____

Suplente: _____

Realizado el acto de defensa y lectura de la Tesis el día.....de.....de 20...
en la E.T.S.I. /Facultad.....

Calificación

EL PRESIDENTE

LOS VOCALES

EL SECRETARIO

INTENTIONALLY LEFT BLANK

Acknowledgement

First and foremost, I am grateful to the mighty of Allah for enabling me to complete this Ph.D. journey. It would not have been possible to be writing without the help and support of the kind of people around me, especially to my supervisor, Professor Dr Gustavo Alonso Rodrigo for his continues support and encouragement. I offer my sincere appreciation for the learning opportunities provided where there's no single negative feedback in every appointment and meeting. With his positive 'aura' and advice that keep me move on until now.

Above all, I would like to thank my husband Muhamed Roihan Yusoff, for his personal support and sacrifices. His great patience and love at all the time have made my journey complete, which my sheer expression of thanks does not suffice. To my both princesses Haaniyah and Ameena, you both might not understand now, but thank you for the cuddly and kisses when I need it most. A simple gesture like running and hugging once I came back from the University such a sweet honey added to my tea.

My parents Haji Mohd Noh and Hajjah Bibah Uyub, my siblings, Along Hariati, Angah Hairanni, Abg teh Hazrul Hafizi and my little brother Hazizul Hanafi, brothers and sisters in law, for unequivocal support throughout. I will never forget how supportive they are in giving me the moral support and unconditional love. My late mothers in law passed away in my first year of the Ph.D. journey. Her support and warm thought and love will always be with me, her courage raising her eight children all by herself is always be my idol, on how strong she is. "Birds don't just fly; they fall down and get up. Nobody learns without getting it wrong." May Allah bless her soul, Amen.

My deepest appreciation goes to Professor Angel Alvarez Rodriguez & wife, who is helping us lots with many things, academic and personnel. The kids will always remember you as professor grandpa. Not to forget, my mentor that always keep me stronger with all his motivation advise Professor Haji Ahmad Zahir. Thank you to UniKL/MIAT for supporting my family and me to be here, financial and continuous support.

Appreciation also goes to Professor Arturo Benito in guiding me since my first master in the year of 2009 where his advice and unsurpassed knowledge in the field of air transportation and the environment. I am also indebted to all professors in air transportation department and not to forget Mamen and friends whose always be my 'unofficial Spanish teacher.' I am glad I know all of you.

I would like to express my appreciation to Airlines Systems, a technical service department, record technical department, and mostly personnel in engineering and maintenance. More than 50 peoples if need to mentioned all. All the contribution, advice, knowledge, leads me to find the light for my Ph.D.

I would like to acknowledge, Alberto Blanch and friends From SENASA under project ITAKA. Even though my contribution is very little, but my experiences lead to enhancing my journey.

I also would like to acknowledge my friends who are like my family here in Madrid, Judy & Julien, Sujith & Ramy, Adeel & Saba, Bayajid & Marina, Gowtham & Yaimini, Nages, Enian, Larry, Lu Yin, Shah & Imran, Fatema, Fatin, Ammar, Joaquin, and to my Clinic colleague in Malaysia Dr. Sue, Dr. Mulia, Dr. Husri, Dr. Nurul, Dr. Ley, Dr. Shahrul, Dr. Aida, Dr. Yatie, Emma to only some of whom it is possible to give a particular mention here. Also to Belqis & family for offering a friendship that, will last forever. Finally, I cannot express enough thanks to Maria Secretariat postgrados ETSIA, Arancha Lauder & Carmen from International office for their patience in entertaining all questions.

I wish everybody all happiness and hope the friendship will not end here.

España siempre estará en mi corazón.

Dedication to;
My husband Roihan and my princesses; Haani & Ameena
I love you to the moon and back.....

Table of Contents

Acknowledgement	iii
Table of Contents	vi
List of figures	xv
List of Tables	xviii
Appendices	xx
Abbreviations	xxi
INTRODUCTION	1
1.1 Background	3
1.2 Problem statement	8
1.3 Objectives of the study	9
1.4 Research question	10
1.5 Significances of the Study	10
1.6 Limitation	11
1.7 Thesis Structure	11
1.8 Conclusion for Chapter 1	13
LITERATURE REVIEW	16
2.0 Introduction	16
2.1 Reviews from Reports and Documentations	16
2.2 Aviation Biofuel and IATA's Four Pillar Strategy	18
2.3 Background EU legislation on biofuels	23
2.4 Biofuel flight test and schedule from 2009 until May 2016	27
2.5 Current energy used in aircraft engine	32
2.6 Aviation drop in biofuel - Requirements	40
2.7 Aviation and Environment	44
2.8 Fuel Revolution	49
2.8.1 Biojet fuel overview- Biofuel generation	51
2.8.2 Conventional fuel-First generation	52
2.8.3 Advanced Biofuels	53
2.8.4 Short and long terms feedstock	54
2.8.5 Biofuel process methods	57
2.9 Biofuel and the impact on aircraft performance – BurnFAIR project	58
2.10 The current state of engine- Maintenance and Cost	63
2.11 Biofuel and the impact in Maintenance Practice into existing fleet	66
2.11.1 Operation	68
2.12 General Maintenance scope	69

2.12.1 Maintenance “check “– Schedule Maintenance.....	70
2.13 Conceptual framework and hypothesis analysis	72
2.13.1 Hypothesis Analysis.....	72
2.13.2 Conceptual Framework.....	73
2.14 Conclusion for Chapter 2	74
RESEARCH METHODOLOGY	77
3.0 Introduction	77
3.1 Research Objectives and Research Questions.....	78
3.2 Research design	78
3.2.1 The phase 1: Contents Analysis and Correlational	81
3.2.2 The Phase 2: Preliminary Questionnaires Survey	82
3.2.2.1 Aim of Phase 2	82
3.2.2.2 Research questions	82
3.2.2.3 Research flow and target.....	82
3.2.3 The Phase 3: Data Collection and Analysis using Risk Assessment.....	84
3.2.3.1 Aim of phase 3	84
3.2.3.2 Research Questions	84
3.2.3.3 Research subject and target	84
3.2.3.4 Risk assessment	86
3.2.4 Phase 4: Discussion on Key finding and Structured Interview validation.....	88
3.2.4.1 Aim of phase 4	88
3.2.4.2 Research question.....	88
3.2.4.3 Research flow and target.....	88
3.2.4.4 Storage Stability	89
3.2.4.5 Composition	91
3.2.4.6 Thermal stability	91
3.2.4.7 Combustion	93
3.2.4.8 Contaminants.....	94
3.3 Trustworthiness	95
3.4 Ethical.....	95
3.5 Conclusion for Chapter 3	95
RESULT AND ANALYSIS: PHASE 1 - CONTENT ANALYSIS OF BIOJET FUEL REPORT AND AIRCRAFT ENGINE MAINTENANCE.	97
4.0 Introduction	97
4.1. Preparation phase – CFM 56 Turbine Engine Fuel System and its relationship to biojet fuel Maintenance	97
4.2 Organizing Phase.....	100
4.3 Reporting Phase – A new Maintenance paradigm for Biojet fuel correlation.....	104

4.4 Conclusion for Chapter 4	107
RESULTS AND ANALYSIS: PHASE 2 - PRELIMINARY QUESTIONNAIRES	110
5.0 Introduction	110
5.1 Research Objective:	110
5.2 Research Methods:	110
5.3 Research Results:	111
Section A: Demographics	111
5.3.1 Gender of Respondents	111
5.3.2 Age Frequency, Position Frequency and Length Experience in Aviation Respondents	112
Section B: Personal Knowledge about biojet fuels in Aviation	115
Section C: The feasibility of biojet fuels in Aviation.....	117
Section D: Impact the usage of biojet fuels	119
5.4 Discussions for Chapter 5.....	123
RESULTS AND ANALYSIS PHASE 3 & 4: BIOFUEL ADAPTATION IN AIRCRAFT ENGINEERING AND MAINTENANCE- A STUDY ON ITS RISK	126
6.0 Introduction	126
6.1 Problem Statement.....	127
6.2 Research Objectives.....	127
6.3 Research Methodology- Structured Interview	127
6.4 Data Collections and Analysis – Phase 3	128
6.5 Data risk evaluation	129
6.6 The risk and its impact	136
6.7 Analysis and discussion	139
6.8 Phase 4: Validation interview	140
6.8.1 Background Information:	140
6.8.2 The purpose of this interview	140
6.9 Phase 4 Data Collection:	140
6.9.1 Research methods:	140
6.9.2 Research Design:.....	141
6.9.3 Ethical thesis	142
6.10 Data results and Analysis phase 4.....	143
Section 1 - Demographic.....	143
Section 2 of Background of research	144
i. Storage stability – (water and biological growth).....	144
ii. The composition of the biojet fuel compares to Jet A fuel.....	145
iii. Fuel thermal stability in the Jet fuel compares to biojet fuel.	146
iv. The fluidity of the Jet A/A-1 fuel compares to biojet fuel.....	147
v. The combustion properties comparison from Jet A to biojet fuel.....	148

vi. The contaminants for Jet A/ A-1fuel compares to biojet fuel.....	149
Section 3 consists of questions on general understanding on biojet fuel.	150
6.11 Discussion and conclusion for Chapter 6	153
ANALYSING THE IMPACT FACTORS OF BIOFUEL TO THE COMMERCIAL AIRCRAFT OPERATION AND ECONOMIC ANALYSIS TOWARDS ITS SUSTAINABILITY.	
7.0 Introduction	155
7.1 The Risks and the Need for a New Approach	157
7.2 The risk outcomes.....	157
7.3 The opportunity- New economy and alliances	158
7.4 Proactive and predictive monitoring systems	161
7.5 The regulatory- Energy Policy in Incentives policies being applied in the world.....	162
7.6 Discussion.....	171
7.7 Conclusion for Chapter 7.....	176
SUMMARY, CONCLUSION AND FUTURE STUDY	179
8.0 Introduction	179
8.1 Summary of the previous finding.....	179
8.2 Recommendation.....	181
8.3 Significant Contribution	182
8.3.1 Maintenance view.....	182
8.3.2 Current incentive rules and mechanisms to promote biofuel use in the EU and their possible application to the civil aviation sector	183
8.4 Future studies	184
Appendices.....	187
References	205
Resume	A

INTENTIONALLY LEFT BLANK

Abstract

The purpose of this research is to engage the current issues of new alternative energy (Biojet Fuel) to be used in air transport sector. The adaptation to Aircraft Engine Maintenance and different possibilities of application of incentive mechanisms available, especially in European countries will lead to the air transport and renewable energy that are creating a new environment towards sustainability. New alternative energy approaches primarily concentrate on accomplishing two primary goals; firstly, to cut the dependency on fossil fuel and switch it to renewable energy, and secondly, to reduce carbon emissions.

The thesis investigates the usage of new alternative energy and how it affected the aircraft engine maintenance. Maintenance, Repair and Organisation (MRO) need to adapt and embrace the transition, especially shifts in focusing the global biofuel trend following the approval of the authority and engine producer. Although the scenario is too early to forecast the total benefit of Biojet fuel to Airlines cost as a whole, maintenance, particularly can have the direct impact when reducing in Maintenance visit lead to reducing the Maintenance cost. The methodology employed in this study divided into four phases: Phase 1 to Phase 4. The phase 1 will be covering up the details analysis and document analysis in looking into Reports and Aircraft Engine, Components and fuel system Maintenance Manual. The correlation between both will be conveyed to Phase 2, 3 and 4 in the data collection and analysis. Data Collection and analysis and triangulation resources will be applied to cover the conclusion and discussion of the main findings.

This thesis scrutinised the biojet fuel which used for the aviation industries by looking at its urgencies, risks, and opportunities, where the relationship on aircraft maintenance, economic analysis, and sustainability will be the primary focus. The urgency of the need for renewable energy has been captured by looking at the high peak of oil price and the contribution of emissions from air transport. The risks focused on the jet fuel characteristics and the requirements that were needed to be met by 'drop in fuel', whereby the complexity of aviation fuel was studied to ensure particular qualities and its relationship towards maintenance specification. Based on the economic analysis, the biojet fuel would create an opportunity for developing the new economy and new alliances. In return, expands the

business, and consequently, creates more jobs in the most sustainable approach. Biojet fuel as renewable energy in the air transport should grow rapidly to support and sustain the industry.

Airline industries need to ensure that this adaptation will create a smooth transition without any major conversion on the whole system. Besides, This paper deals with the need of introducing biofuels for the use of the civil aviation sector, and the different possibilities of application of incentive mechanisms if the existing market conditions do not allow their direct commercialisation. As the price of petroleum remains high, the fossil source continues to be sufficient, and the interest in alternative jet fuels continues to grow since it relates to cost benefit. The study also recommended the need for further understanding of the role of incentive can offer in increasing the usage of biojet fuel. The findings contribute to shaping the research agenda for future biojet fuel in the relationship to maintenance analysis studies.

Resumen en Español.

El propósito de esta investigación es el estudio de los problemas actuales relativos a los nuevos combustibles alternativos (en particular combustible de origen bio) para ser utilizados en el sector del transporte aéreo. La adaptación del mantenimiento del motor del avión y las diferentes posibilidades de aplicación de mecanismos de incentivos disponibles especialmente en países europeos se encuentran entre los principales problemas en cuanto a la utilización a gran escala de los biocombustibles en la aviación comercial. Las nuevas alternativas de energía se centran sobre todo en lograr dos objetivos principales; en primer lugar, reducir la dependencia de los combustibles fósiles y cambiar a energías renovables y en segundo lugar, a reducir las emisiones de dióxido de carbono.

La tesis investiga el uso de nuevas energías alternativas y cómo afecta a las operaciones de las aeronaves de transporte, fundamentalmente en lo relativo al mantenimiento del motor del avión. Las operaciones de mantenimiento y reparación (MRO) necesitan adaptarse y realizar la transición, especialmente cambios en el enfoque a seguir tras la aprobación de la autoridad aeronáutica y el fabricante del motor. Aunque es demasiado pronto para predecir el impacto de los biocombustibles en la economía de las compañías aéreas, en el mantenimiento particularmente puede tener el impacto directo de reducir el coste al disminuir los intervalos entre inspecciones. La metodología empleada en este estudio se divide en cuatro fases: fase 1 a fase 4. La fase 1 que cubre el análisis de datos y análisis de documentación (Manual e informes de mantenimiento y datos técnicos de motores de aeronaves, componentes y sistema de combustible). La correlación entre ambos será utilizada en las fases 2, 3 y 4 en la recopilación de datos y análisis. La recopilación de datos y el análisis y triangulación de recursos se aplicarán para cubrir la conclusión y la discusión de los resultados principales.

Esta tesis analiza el biocombustible que se utiliza en la industria de la aviación mirando sus urgencias, riesgos y oportunidades, donde la relación entre mantenimiento de aeronaves, el análisis económico y la sostenibilidad es el enfoque principal. La urgencia de la necesidad de las energías renovables ha sido capturada considerando el alto precio del petróleo y la

contribución de las emisiones del transporte aéreo. Los riesgos se centró en las características del combustible de jet y los requisitos necesarios que deben cumplir los combustibles “drop-in”, por lo que la complejidad del combustible de aviación fue estudiada en sus cualidades particulares y su relación con la especificación de mantenimiento. Basado en el análisis económico, el combustible biojet crearía una oportunidad para el desarrollo de la nueva economía de las compañías aéreas y nuevas alianzas. El combustible biojet como las energías renovables en el transporte aéreo debe crecer rápidamente para apoyar y sostener la industria.

La industria de las líneas aéreas debe garantizar que esta adaptación va a crear una transición suave sin ninguna transformación más profunda en todo el sistema. Además, este trabajo aborda la necesidad de la introducción de biocombustibles para el uso del sector de la aviación civil y las diferentes posibilidades de aplicación de mecanismos de incentivos económicos si las actuales condiciones del mercado no permiten su comercialización directa. Indudablemente, al margen de consideraciones ambientales, el interés en los combustibles alternativos dependerá de su relación coste beneficio. El estudio también recomienda la necesidad de mayor comprensión del papel que los incentivos pueden ofrecer cada vez más el uso de combustible biodiesel. Los resultados contribuyen a dar forma a la agenda de investigación futura de los biombustibles en relación a los estudios de análisis de mantenimiento.

List of figures

Figure 1: Aviation Integrated Modelling Project (Adapted from Vera-Morales and Hall, 2010).....	1
Figure 2: ASTM D4054- Drop in alternative fuel with unchanged operating limitation	2
Figure 3: Turbine engine sections with complete combustion products.	4
Figure 4: Historical and projected CO ₂ emission by methods of transportation (1979-2050) Source: IEA (2005) and WBCDS (2004b)	6
Figure 5: Schematic comparison of the width of Solar Impulse 2 aircraft with Boeing 747. Source: Boeing	7
Figure 6: Lifecycle greenhouse gas emissions by fuel type.....	8
Figure 7: Conclusion on chapter 1	13
Figure 8: International passenger growth by region	16
Figure 9: IATA's Four-pillar Strategy	19
Figure 10: Biojet fuel flight test and scheduled flight according to the region.	29
Figure 11: Relative variation of US dollar and oil price values.	38
Figure 12: Cost of Jet kerosene versus selected biofuel raw materials 1999-2014. Source: Index Mundi, (Hind, 2014)	39
Figure 13: Jet fuel distilled out of crude oil at around 200 – 250°C	41
Figure 14: Aviation fuel distribution system.....	42
Figure 15: Fossil fuel and Biojet fuel affected the emissions to Air, water, and Land.....	45
Figure 16: Long-term targets for international aviation CO ₂ emissions.....	46
Figure 17: Airbus and Boeing selling and building planes from 2004 - 2014.....	47
Figure 18: The fuel efficiency of new aircraft has improved from 1955- 2015.	48
Figure 19: Fleet evolution from 2004-2013 for single Aisle.....	49
Figure 20: Conventional and Advance Biofuel	52
Figure 21: Jatropha Crucas oil yields from the first to the fourth year. Source: IATA- Brazil jatropha	54
Figure 22: The Comparison of the Physical Properties Of Algae Biofuel And Fossil Fuel.	57
Figure 23: Honeywell HTF700 Engine Durability Test (Source: 2012 CRC Aviation Fuel Meeting Presentation, USDOT/RITA/Volpe May 2, 2012)	59
Figure 24: BurnFAIR Engine trend monitoring results for Take-off and Cruise data	61
Figure 25: Co ₂ emissions result in 10% and 20% Farnesane with a reference to normal Kerosene	62
Figure 26: No _x emissions result in 10% and 20% Farnesane with a reference to normal Kerosene	62
Figure 27: Soot emissions - number and diameter or particles result in 10% and 20% Farnesane with a reference to normal Kerosene	63
Figure 28: Airline operational cost breakdown	64
Figure 29: Direct Maintenance Cost by segment in the year of 2009 until 2013 by IATA.....	65
Figure 30: An example of B737 Classics Schedule Maintenance programme development Source: Boeing	67

Figure 31: Hypotheses in looking at the problem of safety, cost, timing, awareness and policy perspectives in sustainability approach.....	73
Figure 32: Bio jet fuel conceptual framework	73
Figure 33: CAAFI- Targeting Cost Competitiveness.....	74
Figure 34: CAAFI Cooperative RDD & D efforts.....	75
Figure 35: Research Methodology	77
Figure 36: Research Flow	79
Figure 37: Research Design	80
Figure 38: Multiple Resources in generating the content analysis correlation	81
Figure 39: Five general steps to risk assessment.....	87
Figure 40: Water composition in Biofuel flight test compares with conventional Jet fuel	90
Figure 41: The composition of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae comparing with Aromatics.....	91
Figure 42: Thermal stability of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae	92
Figure 43 Combustion properties of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae	94
Figure 44: Contaminants in Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae	94
Figure 45: Content Analysis Inductive method.....	97
Figure 46: Biojet fuel report from authority and Manufacturer.....	99
Figure 47: Content Analysis Deductive method	99
Figure 48: Maintenance Manual related	100
Figure 49: Open coding from various reports.....	101
Figure 50: Block diagram of Fuel Pump Operations Argo-Tech.....	103
Figure 51: Specific gravity position setting in MEC requirements.....	104
Figure 52: Correlation from Biojet fuel into aircraft maintenance.....	108
Figure 53: Gender differences	111
Figure 54: Age Frequency, Position Frequency and Length of experience in Aviation of Respondents	113
Figure 55: Section B: Personal Knowledge about biojet fuels in Aviation	115
Figure 56: Section C: The feasibility of biojet fuels in Aviation.....	117
Figure 57: Section D: Impact the usage of biojet fuels	119
Figure 58: Question D1 on better environment	120
Figure 59: Question D2 on better fuel cost	121
Figure 60: Question D3 on engine performance	121
Figure 61: Question D4 on Saving Airlines for maintenance cost.....	122
Figure 62: Question D5 Sustainable aviation industries	122
Figure 63: The impact of using Biojet fuel based on 40 respondents	123

Figure 64: Percentage of respondents from various Engineering and Maintenance Department	130
Figure 65: Respondents major concerns with biojet fuel	152
Figure 66: The impact factors of biojet fuel on commercial Aircraft.....	156
Figure 67: Advantages of biofuel from economic perspectives	161
Figure 68: Steps of implementing Cost benefit analysis	162

List of Tables

Table 1: The world transport energy use in 2000 according to modes of transportation.	5
Table 2: A summary of biofuel tests performed on commercial flights	29
Table 3: Evaluation BioSPk report (2009) for different types of biomass versus traditional jet fuel ...	32
Table 4: Various consortia for the biofuel development(IATA, 2013a, 2015; ITAKA, 2012)	43
Table 5: Fuel readiness level on the ICAO environment report (2010)	51
Table 6: The sustainability in biofuel generation by Awudu and Zhang (2012)	53
Table 7: A summary of the short and long terms of biomass.....	57
Table 8: Selected announced SAJF purchased agreements as November 2015	58
Table 9: Turbine Engine Manufacturer and Maintenance Programme.....	65
Table 10: Development process in operations time and goal adaptation.....	69
Table 11: Example of questions Section D Impact of the usage of biojet fuel	84
Table 12: Target group in Engineering and Maintenance department.	85
Table 13: Table of Impact Analysis.....	88
Table 14: Section 2 (Case studies from Bio-SpK)	89
Table 15: The composition of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae comparing with Aromatics, and Sulphur.	91
Table 16: Unit of analysis: Biojet fuel Report.....	98
Table 17: Unit of analysis: Maintenance Manual Related	99
Table 18: Maintenance paradigm in RCM adaptation from (SAE, 2002)(Moubray, 1995)	105
Table 19: Components, Functions and its relationship to aircraft engine maintenance.....	106
Table 20: Gender of Respondents	111
Table 21: Age of Respondents	112
Table 22: Positions of Respondents in the Industry	112
Table 23: Length of experience in Aviation of Respondents	113
Table 24: Personal Knowledge about biojet fuels in Aviation	115
Table 25: The feasibility of biojet fuels in Aviation.....	117
Table 26: Questions (D1-D5) impact the usage of biojet fuels	119
Table 27: The impact of the usage of biojet fuels.....	120
Table 28: Respondents from different Engineering and Maintenance Department.....	129
Table 29: Identification of Risk Classification from the interviews and questionnaires.....	134
Table 30: Risk assessment evaluation.....	135
Table 31: Risk Assessment Matrix on Probability and Impact	136
Table 32: Risk Assessment Matrix on Impact and Probability analysis on Biojet fuel adaptation	138
Table 33: Biojet fuel sustainable in four dimensions for Air Transport development on concentric circle adaptation in Aircraft MRO.	142
Table 34: Details background such gender, years of experience, and position in the company	143

Table 35: The table portrays an example of a SWOT analysis that can be identified for biomass use to produce renewable energy.....	158
Table 36: US Federal programs are providing direct or indirect incentives for biofuels (Congressional Research Service).....	164
Table 37: Blending obligations in the EU, measured in % of energy (Vecchiet, 2011). *indicates % by volume	169

Appendices

- Appendix 1.** Engine Manufacturer Maintenance Programme
- Appendix 2.** Questionnaires form Phase 1
- Appendix 3.** Consent letter for Phase 3 Interview: Biojet fuel impact and its adaptation to aircraft maintenance
- Appendix 4.** Interview questionnaires and Pilot Study Questionnaires Phase 3
- Appendix 5.** 'Consent letter for Phase 4 Interview: Case Study on Biojet fuel flight test and its adaptation to aircraft maintenance
- Appendix 6.** Validation Interview questionnaires Phase 4
- Appendix 7.** Potential future evolution of selected feedstocks biofuel production, compared with fossil kerosene (2014 economic conditions)

Abbreviations

Chemical compound
Carbon dioxide (CO₂)
Carbon Monoxide (CO)
Hydrocarbons (HC),
Methane (CH₄)
Nitrogen oxides (NO_x)
Non-methane volatile organic compounds (NMVOC)
Sulphur oxides (SO_x)
Water vapour (H₂O),

A4A	Airlines for America
AFTF	Alternative Fuels Task Force
AIREG	Aviation Initiative for Renewable Energy in Germany
AMM	Aircraft Maintenance Manual
ANSPs	Air Navigation Service Providers
APU	Auxiliary Power Unit
ASBUs	Aviation System Block Upgrades
ASTM	American Society for Testing and Materials
ATA	Air Transport Association of America, Inc.
ATM	Air Traffic Management
BMWi	Federal Ministry of Economics and Technology
BTL	Biomass to Liquid
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAEP	Committee on Aviation Environmental Protection
CNAGA	Companhia Nacional de Armazéns Gerais Alfandegados
CRC	Australian Government's Cooperative Research Centers
DLR	German Institute for Aerospace and Aviation
EAG	Environment Advisory Group
EC	European Commission
E&M	Engineering & Maintenance
EU	European Union
EU-ETS	European Union Emission Trading Scheme
GHG	Green House Gases
GMTF	Global Market-based Measures Technical Task Force
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IGFAAF	ICAO Global Framework for Aviation Alternative Fuels
ILUC	Indirect Land Use Change
INOCAS	Innovative Oil and Carbon Solutions
IPC	Illustration Part Catalog
IPCC	Intergovernmental Panel on Climate Change
ITAKA	Initiative Towards sustainable Kerosene for Aviation
MRB	Maintenance Review Board
MRO	Maintenance Repair Organisation

NGO	Non-Governmental Organization
OBSA	Observatory of Sustainability in Aviation
OEM	Original Equipment Manufacturer
RF	Radiative Forcing
RPK	Revenue Passenger Kilometer
RSB	Roundtable on Sustainable Biofuels
RTK	Revenue tonne kilometer
SAFRM	Sustainable Aviation Fuel Road Map
SAFUG	Sustainable Aviation Fuel Users Group
SENASA	Servicios y Estudios para la Navegación Aérea y la Seguridad Aeronáutica
SESAR	Single European Sky ATM Research
SkyNRG	Sky energy the fuel future
SPK	Synthetic Paraffinic Kerosene
SWAFEA	Sustainable Way for Alternative Fuel and Energy in Aviation
UNFCCC	United Nations Framework Convention on Climate

INTENTIONALLY LEFT BLANK

CHAPTER 1

INTRODUCTION

Throughout the history of air transportation, continuous development and improvement have been captured, driven by fuel efficiencies, cost, and environmental considerations. The aviation sector and the land transportation cannot be compared for the sustainability as the automotive has already found their solution by using electric, batteries, and hydrogen. In contrary, the aviation has considered biojet fuel as their near and mid-term solutions for sustainable alternative energy.

According to Vera-Morales and Hall (2010), the models for aircraft and engine technologies, air transport demand, airport activity, and airspace operations are all connected to global climate, local environment, and economic impact blocks, as shown in [Figure 1](#).

Figure 1: Aviation Integrated Modelling Project (Adapted from Vera-Morales and Hall, 2010)

Alternative fuels for aviation is not something new. It has been there since the early days of turbine engines. The types of fuels that are required to be stored at extremely low

temperature to maintain its liquid state is known as 'Cryogenic fuels,' such as liquid hydrogen and other more exotic fuels, such as boron compounds, which were studied in the 1950s and 1960s (Maxwell Smith, 1979). Furthermore, the energy crisis before 1973 when the fuel prices increased dramatically leads to the research of alternative in the USA.

Airlines need to adapt to the new energy, but the most necessary part is ensuring that it can be used effectively without any alteration to the systems, and it is affordable to maintain it.

The ASTM D4054 was developed as a guide related to testing, and the procedures ensuring certification of the drop in Alternative fuels have remained unchanged to the limitation of Engine operating and aircraft operations, as well as aircraft flight manual as in [Figure 2](#) below. Besides, this indicator needs to relate and ensure that the transition into the prolonged future towards engine systems can continually perform its function in the levels of reliability and safety (Kinnison, 2004).

Figure 2: ASTM D4054- Drop in alternative fuel with unchanged operating limitation

Source: ASTM D4054

Sustainable, advanced-generation aviation biofuels will play a large role in reducing CO₂ emissions (Kramer, 2013; ATAG, 2012). The European ETS Directive (EC, 2008) considers a

zero emission factor for aviation biofuels, although assessments of life-cycle CO₂ emissions typically show a reduction potential compared to fossil jet fuel in the order of 30-90%, depending on feedstock and production processes (Stratton et al., 2010; Vera-Morales and Schäfer, 2009).

On the biofuel usage in aviation, most of the specification and operational questions have been already answered, and no technological show-stopper is seen. However, the economic viability is still far from being made secure (Halog & Manik, 2011).

Data suggest that the proportion of biofuels in total fuel consumption of commercial aviation was 0.5% in 2009 and will rise to 15.5% in 2024 in a “moderate” scenario, and to 30.5% in an “ambitious” scenario (Sgouridis et al., 2011). In the European Union, the European Commission has launched the “European Advanced Biofuels Flightpath”, an industry-wide initiative to speed up the market uptake of aviation biofuels in Europe. It provides a roadmap to achieve an annual production of two million tonnes of sustainably produced biofuel for aviation by 2020 (EC, 2011). This target was one of the goals of ITAKA program and, after realising the huge difficulties are existing, it was delayed until the year 2030.

This research provided series and parallel studies that looked into aviation alternative energy, focusing on biojet fuel, to be used in commercial aviation. Besides, the common ground of aviation mission and visions towards the sustainability to all airlines around the globe discusses the incentive and mechanisms to promote biofuel will be reviewed. Moreover, the area of interest is focused on its relationship towards aircraft maintenance performance in general aspects, and test rig was conducted to ensure the characteristics of fuel to be adapted and adopted in maintenance prevention.

1.1 Background

The contributions of the aviation sector to the environment and the development of alternative fuel are the main global issues. [Figure 3](#) shows the complete operation of a turbine engine process. The continuous suction of the airflow in the intake sections and the compression introduces the fuel flow and the primary airflow into the combustion sections.

It will release the heat in combustion section, and converts it into mechanical energy to the turbine section to drive back the compressor, and finally, the exhaust section, where the thrust is released (Sanderson, 1997).

Figure 3: Turbine engine sections with complete combustion products.

Source: Roll Royce's

The contribution of aviation to the greenhouse gas (GHG) emission is 2 to 3%. According to ICAO, this is about to increase by 15% by 2050 at this rate of pollution (IATA Environment, 2009). Aviation has contributed to magnify the effects of pollution by directly affecting the ozone depletion in the upper reaches of the atmosphere. Aviation, climate change impacts are due to both, CO_2 and non- CO_2 emissions. The non- CO_2 emissions include water vapour (H_2O), nitrogen oxides (NO_x), sulphur oxides (SO_x), hydrocarbons (HC), and black carbon (or soot) particles (IATA, 2008).

Aviation contributions to the climate change were 3.5% of the total anthropogenic RF in 1992 (IPCC, 1996). According to Lee et al., (2009), it has been projected to increase to 5% for a mid-range emission scenario by 2050. From the overall transportation sector, it is crucial

to acknowledge the growing distribution of the world energy use and emissions of GHGs (Ribeiro et al., 2007). For an example, in 2004, the transport energy used up to 26% of the total world energy consumption and the transport sector itself was responsible for about 23% of the world energy-related GHG emissions (IEA, 2006) as [table 1](#). The world transport, energy use in 2000, by types of transportation of a total of 77 Energy Use (EJ), road vehicles accounted higher reading. Air transport contributes 11.6 % of its share to the growth rate of energy consumption.

Table 1: The world transport energy use in 2000 according to modes of transportation.

Source: IEA 2006

Mode	Energy use (EJ)	Share (%)
Light-duty vehicles (LDVs)	34.2	44.5
2-wheelers	1.2	1.6
Heavy freight trucks	12.48	16.2
Medium freight trucks	6.77	8.8
Buses	4.76	6.2
Rail	1.19	1.5
Air	8.95	11.6
Shipping	7.32	9.5
Total	76.87	100

With the continuous growth of the global economy without any disruption, robust growth in the world transport, energy at a rate of 2% per year had been forecasted, whereby the energy use in 2030 will be 80% higher than in the year of 2000. According to IEA (2006), the forecast project would remain between 93% and slightly over 95% for transport fuel use over the period. As a result, this is where the connection in the aviation industry sees the hike in CO₂ emissions essentially up to 2050.

From the historical point of view, since 1970 and projected 2050, carbon dioxide emissions that cover all the transport modes as in [Figure 4](#).

Figure 4: Historical and projected CO₂ emission by methods of transportation (1979-2050)
Source: IEA (2005) and WBCDS (2004b)

On the other hand, as in aviation, according to Alonso et al., (2014), in Europe itself the CO₂ emission was a total of 216 million tonnes for 2010, and the projected year may produce 334 million for an Optimistic scenario. The study showed the structure of air traffic, where the distribution covered throughout different countries in the European Union. The structure of the study where the data for fuel consumption and CO₂ emissions were captured by different variables (Alonso et al., 2014).

These rapid changes have a serious effect in creating global carbon neutral, where in this case, the clean new improved engine alone will not work. Adaptation and current works with new 'alternative energy' with zero carbon distribution lead the pollutions towards the direct impact on the atmosphere (IATA 2010). Alternative energy in commercial aviation may utilise biofuel, gas to liquid, solar and hydrogen cells (Daggett et al., 2008; 2007).

Also, Daggett et al., (2007) classified short, medium, and long terms to analyse the different alternative energies in commercial aviation. Fischer-Tropsch is processing the short-term option of synthetic fuels. The potential to release pressure from the demand for pure fuels is from crude oil. However, it does not reduce CO₂ emissions over the entire lifecycle. Moreover, if the additional process-related CO₂ emissions are not captured and sequestered, the total CO₂ emissions may double.

The midterm option offers the biojet fuel to be mixed with the synthetic fuel, which reduces the CO₂ emissions, as it includes a future offer to complete replacement for crude-oil-derived fuels. The detail discussion will be in [chapter 2](#) of the literature review. The final long term option is the low-carbon and liquefied gaseous fuels. This is Liquid methane extracted from methane hydrates or perhaps liquid hydrogen produced from nuclear. The solar power can be classified as promising for a long-term option. [Figure 5](#) below shows the comparison of the solar impulse @ aeroplane to Boeing 747 jet.

Figure 5: Schematic comparison of the width of Solar Impulse 2 aircraft with Boeing 747.
Source: Boeing

The Solar Impulse equips batteries that make up the weight penalty up to a quarter of the plane's; 2.5ton (2,300 KG). The batteries that provide the storage energy from the solar are more than 17,000 solar cells and are used throughout the night flight or through the cloudy weather. Also, hydrogen fuel has been tested, and it has been proven to resolve entirely CO₂ emissions. However, technical challenges remain: Low fuel volume density results in weight

tank penalty. Also, the process for producing the fuel needs to be developed; more researchers have to concentrate on economics, and environmental issues need to highlight. As a weight penalty remains a challenge, the Hydrogen cells are mainly not focused in commercial aviation (Adler & Gellman, 2012a).

The greenhouse gas Emission as shown in [Figure 6](#) below, demonstrates their current form, which contributes more CO₂ than Jet A/Jet A-1 hence give jet fuel from plant sources as the second lowest. (ICAO, 2009).

Figure 6: Lifecycle greenhouse gas emissions by fuel type.

Source: Boeing

1.2 Problem statement

To strive for a competent preventive and practical maintenance system that is dependent and easy to use, it has always been the motivation to understand efficiently the relationship of biojet fuel and the management of Aviation engineering and maintenance. New alternative energy might reduce Airlines fuel cost in the future, but in what perspective does the biofuel can minimise the cost of the related maintenance? The detail information for

Engineering and maintenance programme using new alternative energy are incomplete at this moment, including the confirmation of ground support facilities.

The airlines need to adapt to the new energy, but an essential part is to ensure that the new energy can be used efficiently and is affordable to maintain. The Maintenance Review Board (MRB) would need to evaluate the changes in the maintenance programme to check if the tasks need to be eliminated or reinstated. The new energy that discussed in this study derived from biomass, and often called as biojet fuel, biokerosene, aviation biofuels, and renewable jet fuel.

In some cases, the maintenance programme needs to be adjusted to the introduction of new elements to ensure its reliability and to conduct analyses in the event of system failure or component failure (Sundaram et al., 2011). In identifying the correlation between the biojet fuels to Engine Maintenance, this research discusses the usage of biofuel in an aircraft engine, specifically the Boeing 737-400 engine, and the evaluation of maintenance prediction for MRO related to the succeeding biojet fuel report from Bio-SPK (2009).

The economic analysis in identifying the incentive and mechanism in understanding further the implication in biojet fuel usage will be vital. Subsidies, on the other hand, are forms of government financial support for activities believed to be environmentally friendly. Rather than charging a polluter for emissions, a subsidy rewards a polluter for reducing emissions. (Noh, Benito, & Alonso, 2016)

1.3 Objectives of the study

With numerous sources and evidence on many issues, several objectives were formulated about the study:

- RO 1)** To critically review the issues concerning of usage biojet fuel for aviation.
- RO 2)** To identify the maintenance of aircraft engine in the usage of new energy (biojet fuel)
- RO 3)** To investigate the impact of air transport industries when using the biojet fuel
- RO 4)** To identify the risk impact of the budget fuel on aviation maintenance through a maintenance visit in various departments

RO 5) To discuss the implications of the biojet fuel used in commercial aviation in aircraft maintenance and economic review.

1.4 Research question

This study was aimed to answer the following questions:

RQ 1) What is the relationship between biojet fuel and aircraft maintenance performance?

RQ 2) What are the impacts of biojet fuel to commercial aircraft maintenance and operations?

RQ 3) What are the risk factors that influence biojet fuel to aircraft maintenance?

RQ 4) What are the economic outcomes from biojet fuel?

1.5 Significances of the Study

The findings of this study will redound to the benefit of aviation society, considering that biojet fuel plays a major role in the development towards energy and environmental sustainability. The increased number of the result from industries and application towards maintenance can be correlated, by understanding the needs of the biojet fuel and adaptation to maintenance, the biojet fuel roadmap can be assured when reducing in maintenance visit will be reflecting the deduction in the Airlines cost.

This research looked into many angles and aspects of the new alternative energy and its relationship to aircraft maintenance performance. Some of the significances are:

- Feasibility of deployment of alternative energy through biojet fuel and MRO were analysed using the documents and content analysis.
- Successful level for maintenance is complete if biojet fuel can reach its sustainability, reliability, availability, and finally, maintainability.
- Discussion in reducing the maintenance visit will lead to reducing maintenance cost.
- Observations related to the urgency, the risks, and the opportunities of biojet fuel in the aviation industry looking into the economic analysis of incentive and mechanism to promote biofuel for the civil application used.

1.6 Limitation

Identification on limitation: The restriction from the maintenance department in giving the real and complete data reflected the study. The policy and the rules of the company in handing out the details and data were seen as compromising the safety and the sensitivity of the corporate information. The potential impact on the actual data on components analysis after using the biojet fuel and how it will affect the cost of maintenance refined the quality of the findings and the ability to answer the research question adequately.

Reflecting move: The details of the data have been replaced by in-depth documents contents analysis subjected to the maintenance carried out. The types of maintenance check provided greater depth, helped to explain the nature of the limitations, and justified the benefits throughout the research process. Therefore, this restriction reduced the in-depth outcomes of cost analysis, but in another way, increased the ability to make a critical point in maintenance and its economic analysis through incentives and mechanism to promote biofuels with the greatest impact.

Forward-looking move: With the limitation, the progress in identifying the benefits in various angles and contexts, and the collective aims had been even broader and was not just specific for cost alone. Within this limitation also, future research can be carried out for more accurate analysis in the details and a prediction model can be adapted.

1.7 Thesis Structure

Chapter 1 Introduction

This chapter establishes the context and nature of the research problem and the objective.

Chapter 2: Literature Review

A literature review of the Biojet fuel literature will help to study the usage of Biojet fuel in the aviation industry. This section will explore the airlines that use the Biojet fuel and are there any issue that has faced regarding the maintenance line. In this chapter also will be studied more specifically on the Aviation and Environment concern, with the fuel price and the incentive available in the United States and European countries. The hypothesis was

developed in this chapter together with the conceptual framework in scrutinising the research direction.

Chapter 3: Methodology

This section will introduce the methods that are used to answer the research objectives developed from the problem statement mentioned. The methods used are mix methods where the qualitative method that focuses on the combination of unstructured interviews and approved report base on related documentation and the Quantitative method to support the findings. In this research, it is divided into four phases.

Phase 1 is the contents analysis in merging the data from the reports and authority in the linkage to Aviation manual. *Phase 2* is act as a preliminary data using questionnaires to 40 respondents in getting the idea of the impact and benefit from biofuel usage in the aviation industries based on finding in phase 1. *Phase 3* is the semi-structured interview in measuring the risk analysis in the Engineering and Maintenance department. *Phase 4* is the structured interviewed purposely to validate the data providing from phase 1 until phase 3.

The respondents were designated on the volunteering basis as Aviation background in maintenance is a major concern. The respondents were based in Malaysia, Singapore, Dubai, Qatar and Singapore.

Chapter 4: Results and Discussion Phase 1. This chapter draws together the findings and analysis from the content analysis.

Chapter 5: Results and Discussion Phase 2.

Chapter 6: Results and discussion on Phase 3 and 4.

Chapter 7: Analysing the impact of biofuel usage in the term of urgencies, risk and opportunity where the incentive and mechanism to promote biofuels were lay out in the economic analysis of energy policies.

Chapter 8: Highlights the main findings of the research study, a summary, and a discussion of the limitations of the research carried out and recommendation for future studies.

1.8 Conclusion for Chapter 1

Figure 7: Conclusion on chapter 1

As a result from the IEA (2006) and as asserted by Daggett et al., (2007), the discussion on the alternative energy in this research referred to biojet fuel, regardless the sources of different types of biomass (which is discussed in detail in the next chapter). As a measurement, alongside the engine fuel system, maintenance was evaluated to capture the

sustainability of the fuel that led to maintainability, and its economic analysis where the result in incentive and mechanism review to European countries and the United States.

This chapter lays out the fundamentals ideas for the thesis report. It introduces the research problem and the research questions. Then, the research was justified as in [Figure 7](#). The revolution and evolution of the biofuel towards aircraft engine maintenance will be review under the impact of the policy, safety and cost. The limitations in this research were spelt out. Based on these foundations, the further report is preceded by a detailed description of the research in the next chapter.

INTENTIONALLY LEFT BLANK

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Before the beginning of this research, correlation to the related works, a study of verities of information and sources was completed to determine if any similar projects or researchers have taken place.

2.1 Reviews from Reports and Documentations

Such varieties mentioned included periodical literature from the authorities (IATA report- Alternative fuel, annual report, environment, Maintenance Cost Task Force), general references, journal paper, dissertation abstract, aircraft maintenance documentation (Aircraft Maintenance Manual, Aircraft Illustrated Part Catalogue, and Aircraft components manual). This also included government body websites, such as CAAFI, SWEFA, RSB, SENASA, AIREG, SAFUG, European Union Directives, Policymaker and many more.

Figure 8: International passenger growth by region

Sources: IATA

Air transport is one of the fastest grown transport sectors. Forecasts give future air traffic yearly growth rates of 4 %. International passenger growth by region can be seen in [figure 8](#) below (GroupTransport Studies, 2008).

Despite the benefits from that growth, there are concerns about the increase in aviation greenhouse gas emissions. The significant growth suggests aviation could become a crucial factor over the coming decades (ATAG, 2011; Macintosh & Wallace, 2009). CO₂ is considered the most important greenhouse gas emitted by aircraft, being aviation responsible for about 3% of global fossil fuel consumption and 12% of transportation-related CO₂ (Simone, Stettler, & Barrett, 2013). Recent studies suggest that if the global economic growth continues, aviation CO₂ emissions are likely to experience a greater than the three-fold increase between 2000 and 2050. (Alonso et al., 2014; ICAO, 2009; Lee et al., 2009)

In response to concerns over the global environmental impacts of aviation, stakeholders have committed to strategies of mitigation related to efficiency improvement (fleet replacement, use of larger aircraft, increased density seating inside aircraft, improvements in Air Traffic Control and Navigation procedures). The calculation of the practical consequences of all those elements is rather complicated, but according to IATA the results show an average improvement in efficiency, measured in ton of fuel per RTK, around 1.9% yearly (IATA, 2013b) for the IATA members, although other studies indicate lower figures (Gössling & Upham, 2009). The ICAO Council, in its climate change mitigation program, set an aspirational target for the World Air Transport sector of 2.0% yearly improvement until 2020.

Sustainable, advanced-generation aviation biofuels will play a significant role in reducing CO₂ emissions (ATAG, 2011; Kramer, 2006). The European ETS Directive (EC, 2008) considers a zero emission factor for aviation biofuels, although assessments of life-cycle CO₂ emissions typically show a reduction potential compared to fossil jet fuel in the order of 30-90%, depending on feedstock and production processes (Hileman et al., 2010)

On the biofuel usage in aviation, most of the specification and operational questions have been already answered, and no technological show-stopper is seen. However, the economic viability is still far from being made secure (Demirbas, 2009; Gorter & Just, 2010)

Data suggest that the proportion of biofuels in total fuel consumption by commercial aviation was 0.5% in 2009 and will rise to 15.5% in 2024 in a “moderate” scenario, and to 30.5% in an “ambitious” scenario (Sgouridis et al., 2011). In the European Union, the European Commission have launched the “European Advanced Biofuels Flightpath”, an industry-wide initiative to speed up the market uptake of aviation biofuels in Europe. It provides a roadmap to achieve an annual production of two million tonnes of sustainably produced biofuel for aviation by 2020 (Kousoulidou & Lonza, 2016).

2.2 Aviation Biofuel and IATA’s Four Pillar Strategy

In developing carbon neutral growth and zero emissions for future, the IATA’s vision and four-pillar strategy can be adapted and implemented (ICAO, 2010). This includes investing in effective planes flying technology and efficient infrastructure building and using positive economic measures (technology, operations, infrastructure, and economic instruments. IATA has embraced a four-pillar strategy as in [figure 9](#) to achieve carbon neutral growth as a milestone on the path to emission free future, whereby in the concurrent time maintenance, reliability and cost need to be deliberated (Ramani, 2009).

IATA's Four-pillar Strategy

Figure 9: IATA's Four-pillar Strategy

Frost and Sullivan

New technology developments

The aeronautical industry is one of the highest R&D investment sectors but, as all the technologically leading sectors, project maturation periods are long, and basic technology research cost is extremely high. The economic life of the products is, by consequence, very long (Jiang, 2013).

The irruption of climatic change as a priority target in the development of new prototypes has put additional pressure on the programs to reduce fuel consumption, already imperative for competitiveness market reasons. ICAO is collaborating in this effort by introducing a new requirement of CO₂ emissions certification for new civil aircraft models. ICAO 38 General Assembly approved the applicable procedures in October 2013 (ICAO, 2013a) and the values not to be exceeded will be included in Annex 16 to the Chicago Convention by 2016, with the aim of the year 2020 application. The implications of new aviation technologies in infrastructure, i.e. airports are also important (Kivits et al., 2010).

The development of biofuels, more specifically drop-in biokerosene (a type of kerosene of biological origin, the specification of which is very similar to oil-derived kerosene and can be

mixed with it without any difference in its use). It is being fostered through the ICAO Global Framework for Aviation Alternative Fuels (IGFAAF) and has been included as well in the work of ICAO Committee on Aviation Environmental Protection (CAEP), with the creation in November 2013 of a dedicated group (AFTF) Alternative Fuels Task Force to design a procedure for quantifying the net life-cycle CO₂ reduction results of the different origin biofuel consumption.

Infrastructure improvements

Insufficient infrastructure supply causes energetic resources waste and an increase in greenhouse gas emissions by three different ways: airport congestion induces additional holdings in the terminal area or flight; airway congestion obliges to fly at non-optimal altitudes and/or speeds, and inadequate airspace structure makes flight trajectories longer than the shortest orthodromic track.

Both United States (NextGen ATM program, FAA, 2015) and Europe (Single Sky program, EUROCONTROL, 2015) are committed to introducing advanced Air Traffic Control Systems in the next decade to obtain fuel consumption efficiency improvements in the 5 to 8% order. ICAO continues to develop and update the necessary tools and guidance to assess the benefit associated with those ATM improvements and the environmental benefits associated with the implementation of the Aviation System Block Upgrades (ASBUs) strategy.

Optimised operation procedures

ICAO has reviewed and updated the circular 303 *Operational opportunities to minimise fuel use and reduce emissions* (ICAO, 2004) to transform it in a Technical Manual, subject to continuous revision and adaptation. This publication covers the whole flight planning procedure and registers the energetic efficiency best practices applied in the different Member States, to facilitate the dissemination within the aeronautical community. A similar document referring to the airline operational practices had been published by the International Air Transport Association (IATA, 2001).

Market-Based Measures (MBM)

Despite the intensification of all those technical actions, it is unlikely that their effects will be enough to mitigate the civil aviation contribution to climate change. Then, some regulatory measures should be needed. During the 2001-2004 period, ICAO studied different market tools to collaborate in emissions reduction, divided into four different categories: Voluntary agreements among Administrations, operators, and manufacturers, taxes on fuel or passengers and cargo, CO₂ charges and emissions trading.

Each option was carefully analysed from the legal, technical and environmental point of view. The conclusion of the study, approved by the General Assembly (ICAO, 2004) showed that a worldwide open Emission Trading System (ETS) was the most efficient market-based mechanism. The use of ETS, basically a *cap and trade* scheme, was approved by the Kyoto Protocol in 1997, allowing sectors in which improvement of energetic efficiency are very expensive, like commercial aviation, to trade emissions allowances with others that can achieve those emissions reductions at a lower cost.

On biofuel introduction and characteristics, ICAO asks the Member States to set a coordinated approach in their national administrations to develop policy actions to accelerate the appropriate development, deployment and use of sustainable alternative fuels for aviation, by their national circumstances.

ICAO will also consider measures to support research and development as well as processing technology and feedstock production to decrease costs and support scale-up of sustainable production pathways up to commercial scale, taking into account the sustainable development of States.

The Aviation biofuel should:

- Achieve important net greenhouse gas emissions reduction on a life-cycle basis, compared with a similar kerosene life-cycle
- Respect the areas of high importance for biodiversity, conservation, and benefits for people from ecosystems, by international and national regulations, converting abandoned pieces of land in productive sites

- Contribute to local social and economic development, creating a new source of revenue, always considering that competition with food and water supply should be avoided.

In the field of economic measures, ICAO has decided to develop a global Market Based Measures (MBM) scheme for international aviation to be approved by the 2016 General Assembly. Two working groups have been formed: a high level one (EAG) Environment Advisory Group to identify the major issues and problems for the Member States and make a recommendation on a global MBM scheme that appropriately addresses them, and identify key design elements, including means to take into account special circumstances and respective capabilities.

The second group, GMTF (Global Market-based Measures Technical Task Force) within the CAEP structure, will evaluate the environmental and economic impact of the considered alternatives, and the mechanisms to be set up to control and monitor their implementation. EAG finished its work in January 2016 and was replaced by a High-Level Group (HLG) in charge of reaching a consensus around a proposal to be presented to ICAO Council in June 2016 and subsequently to the General Assembly in September 2016.

The leading alternatives belong to two different families. On one side, the variants of the ETS applied by the EU, with some particular conditions to respect the wide variety of air transport conditions in developed, less developed and underdeveloped countries. The other options are global carbon offsetting schemes, a possibility supported by the airline industry and other stakeholders, which looks like the most probable option to be adopted.

The ETS option appears to be more efficient in the theoretical analysis because it provides everybody with an incentive to work in emissions reduction, but its mechanism seems to be more complicated to apply. According to the brief experience with the European aviation since January 2012, and offers more difficulties for the introduction of several economic charging levels to discriminate among the States with dissimilar development levels. The offsetting seems simpler to implement but may be too close to tax or charge to be as economically efficient as the ETS.

2.3 Background EU legislation on biofuels

During the past century, there had been some isolated initiatives to use biological resources to produce energy and complement the classic energetic generation from fossil fuels, hydroelectric and nuclear facilities. However, those were independent actions without any coordinated regulatory framework.

The first European Union (EU) intent to regulate and incentivize the use of biomass for energy generation was the Directive 2001/77/EC (EU, 2001a), titled *on the promotion of electricity produced from renewable energy sources in the internal electricity market*. It was approved on September 21, 2001, and published in the Official Journal of the European Communities (OJEC) on October 27, 2001.

The Directive considered that the potential for the exploitation of renewal energy was underused in the Community. The promotion of electricity produced from renewable energy sources was a high priority for reasons of security and diversification of energy supply, of environmental protection and social and economic cohesion, with specific reference to biofuels in the last aspect, as indicated in the 1998 White Paper on Renewable Energy Sources.

This Directive defined *renewable energy sources* as non-fossil energy sources, including wind, solar, geothermal, wave, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases. For the case of *biomass*, the definition was the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of the industrial and municipal waste.

The new Directive defined *biofuels* as a liquid or gaseous fuel for transport produced from biomass and listed a basic, non-exclusive inventory of 10 products qualified as biofuels. In brackets, the most commonly used feedstock for the production of each one of the products:

- *Bioethanol* (sugarcane, corn, cellulosic)
- *Biodiesel* (vegetable oil, animal fat)

- *Biogas* (organic waste)
- *Biomethanol* (wood)
- *Biodymethylether* (agricultural methanol))
- *Bio-ETBE (ethyl-tertio-butyl-ether)* (agricultural ethanol)
- *Bio-MTBE (methyl-tertio-butyl-ether)*(agricultural methanol
- *Synthetic biofuels* (solid biomass, bio-oil and fats)
- *Biohydrogen* (algae, bacteria, archaea)
- *Pure vegetal oil* (oily seeds like Palm, soybean, rapeseed, sunflower seeds)

By the end of 2006, the Commission would prepare an evaluation report, revised every two years, covering:

1. The cost-effectiveness of the measures taken by the Member States to promote the use of biofuels and other renewable fuels
2. The economic aspects and the environmental impact of further increasing the share of biofuels and other renewable fuels
3. The life-cycle perspective of biofuels and other renewable fuels, to (or “intending to”) indicating possible measures for the future promotion of those fuels that are climate and environmentally friendly, and that have the potential of becoming competitive and cost efficient
4. The sustainability of crops used for the production of biofuels, particularly land use, degree of intensity of cultivation, crop rotation and use of pesticides
5. The assessment of the use of biofuels and other renewable fuels on their differentiating effects on climate change and their impact on CO₂ emissions reduction.
6. A review of further more long-term options concerning energy efficiency measures in transport

The revision of the results of this Directive application was not very encouraging. In 2005 the EU transport sector as a whole was using only a 1.02% of biofuel, practically half of the reference target, rising to 2.58% in 2007 what made tough to reach the 5.75% 2010 target.

In 2007 only five EU countries (Austria, France, Germany, Lithuania and Sweden) went beyond 3% in their use of biofuels for transport.

The policies set up by this Directive were developed when the biofuel option seems not to face heavy obstacles for development and public acceptance, with the only exception of land use and consequently output availability, coming into operation from already existing branches of the agricultural industry. However, in the period 2007-2009, some problems appear, rising some doubts about the global performance of the EU policy (Ninni, 2010). These elements may be summarised in three areas:

Indirect environmental effects of the plant cultivation for biofuel production. The production of nitrogen fertilisers uses for improving biomass crop quantities, emitted N_2O , an active greenhouse gas, and may seriously limit global warming reduction by replacing fossil fuels. An even more significant effect may happen by land use change, when cultivating biofuel plants in a former forest or grass prairie, as the CO_2 sink properties of the former land use are lost (Gnansounou et al., 2008). The situation is worse where the virgin forest is cleared since the process is both energy intensive and destroys nature's means of sequestering carbon dioxide (Marsh, 2008). This kind of repercussion, generally denominated ILUC (Indirect Land Use Change) is still a very polemic issue, and there is no general agreement on the optimum way of estimate its life-cycle effect.

Biofuel production may enter in food production competition. As a consequence, food prices will rise as a greater part of the agricultural work is devoted to producing biofuel. According to the World Bank economist Donald Mitchell (Mitchell, 2008), biofuel demand was responsible for 76% of the food price increase in the 2007-2008 period, although other researchers emphasise the role of financial speculation in this phenomenon. The charity Oxfam holds that the subsidies provided by developed countries for biofuel crop cultivation look to poor countries as a tax on food that can tip their populations into starvation. In common with other campaigning organisations, Oxfam is pushing for an end to biofuel subsidies and further biofuel mandates (Marsh, 2008).

Some biofuel policies may be too expensive for the national budgets of the Member States, if we take into account the scarce gains that biofuels could grant regarding sustainability and the reduced amount of overall energy that they could provide.

The issues of social sustainability and competition with food will be the object of a report that the Commission has to present every two years to the Parliament and the Council. Immediately after the publication of the Directive, different ecologist organizations and NGOs published a report calling for a change in the scope. The sustainability criteria in the EU law should be redefined to ensure that all environmental and social impacts are taken into account (for instance, the environmental impact of indirect land use change (ILUC)), thereby promoting only the biofuels that bring genuine overall benefits. Subsequently, the volume targets for biofuels should be replaced with a target for greenhouse gas (GHG) reduction for transport fuels (Birdlife et al., 2009).

In order to solve these and other weak points of the EU biofuel policy, Directive 2009/28/EC (EU, 2009) on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, was approved on April, 23, 2009 and published in the OJEU on June 5, 2009.

This very extensive Directive establishes mandatory national targets for renewable energy sources (RES) share in the 2020 gross final energy consumption. It indicates that to reach these objectives the Member States may apply support schemes and measures of cooperation between the different Member States and with third countries. It also makes a specific reference to the transport sector, where each Member State shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10% of the final consumption of energy in transport in that Member State.

The difference between mandatory global final energy consumption targets differentiated by country and the same common target for transport energy use is justified by the need of ensuring consistency in transport fuel specifications and availability. Because transport fuels are traded easily, the Member States with low endowments of the relevant resources will easily be able to obtain biofuels from elsewhere.

The market impact of transport biofuel is taken into consideration. While it would technically be possible for the Community to meet its target for the use of energy from renewable sources in transport solely from domestic production, it is both likely and desirable that the target will, in fact, be met through a combination of domestic production and imports

A part of these complaints might be answered by the provisions of a new Directive 2015/15137EC (European Union 2015) addressing the ILUC issue, giving the Member States a term up to September 10, 2017. To transpose the Directive into national legislation and up to April 6, 2017 to establish the level of their national indicative sub-targets for advanced biofuels. At this moment, the movement towards advanced biofuels (not derived from food related feedstock's) appears to be very dissimilar in the EU members (Delft, 2015).

2.4 Biofuel flight test and schedule from 2009 until May 2016

The development of biofuel technology for commercial aviation has made extraordinary advances in the last eight years. On February 23, 2008, a Virgin Atlantic B747/400 with General Electric CF6-80C2 engines became the first commercial aircraft in making a flight with a mix of 80% conventional kerosene and 20% first generation biofuel, produced from coconut oil and seeds of babassu palm tree. Since then, more than fifteen airlines have tested the operational possibilities of different aviation biofuels with satisfactory results from the technical point of view.

Airlines fly across continents and need to refuel anywhere, and so the goal is to establish local biofuel value chains on every continent. Such global supply chains require the infusion of huge amounts of capital, which can be achieved only through policy initiatives by airline alliances that combine aircraft manufacturers, allied industries, regulatory organisations, and various governments. The initiatives in this field include the Brazilian Alliance for Aviation Biofuels (ABRABA); the European consortium of airlines and biofuel conversion technology providers led by Airbus; an Australian consortium led by Qantas, The Sustainable Aviation Fuel Users Group (SAFUG). This features 21 airlines, three aircraft manufacturers, and a biofuel conversion technology provider; and the Sustainable Way for Alternative Fuel and Energy in Aviation (SWAFEA) of the European Commission. These alliances are

characterised by a wide variety of involved stakeholders, including the airlines, the aircraft manufacturers, airports, biofuel companies, and petroleum companies, NGOs, governmental agencies and funding agencies.

Another biojet fuel flight was tested on 19th April 2013 for Airbus 320, using 50:50 blend of traditional jet fuel and cooking oil. In the early stage, it could be concluded that an approximately 1-2% fuel efficiency improvement was gained due to its higher density. The biofuel-powered engines also operated at more optimum temperature compared to the engines powered by traditional jet fuel, which would likely present at the long term maintenance cost benefit.

On 17th April 2012, there was a flight test using Boeing 787, which concentrated on Freezing point, thermal stability, and high energy content (Air New Zealand, 2008; Continental Airlines 2009). It was the first use of biofuels on Boeing's new mid-size, twin-engine aircraft that has been capable of flying at long range routes, but its first transpacific flight. The result showed that the flight emissions had been 30% less compared to a similar sized current commercial aircraft, with 10% blend and approximately 20% saving from technology and efficiency advancements offered by the Dreamliner. Other studies conducted by other airlines on the use of biojet fuel can be referred to the table below. With notes taken into consideration of biofuel flight tests, the performances of the engine and the overall performances are highlighted. Also, suggestions had been made that by using biojet fuel, it could contribute a tremendous impact on the airline industry regarding cost benefit. Besides, it causes less pollution and has economic benefits to the airlines.

Figure 10: Biojet fuel flight test and scheduled flight according to the region.

In the year 2013, extended progress had been made by ASTM, where more and broad prospective benefits were achieved, respective to the qualification process. As more biofuel tests and schedule flights were made, a more detailed compilation of data can be recorded as [figure 10](#). This will create a better understanding of the aviation fuel properties and composition, and their effect on aircraft and engines performances. Enhancement leads to greater efficiencies in the alternative fuel approval process. See [Table 2](#) below.

Table 2: A summary of biofuel tests performed on commercial flights

CARRIER	AIRCRAFT	PARTNERS	DATE	BIO-FUEL	BLEND	DESTINATION
Asia Pacific						
Virgin Atlantic	B747-400	Boeing, GE Aviation	23.02.2008	Coconut Babassu	20% one engine	Amsterdam-London
Air New Zealand	B747-400	Boeing, Roll Royce	30.12.2008	Jatropha	50% one engine	Two-hour flight test
JAL	B 747-300	Boeing, P&W, Honeywell UOP	30.01.2009	Camelina, Jatropha, Algae blend	50% one engine	Demo flight
Air China (CA)	B747-400	Boeing, Petro China, Honeywell UOP	June 2011	Jatropha	50% of one engine	Test Beijing airspace
Thai Airways TG	B777-200	Rolls Royce, Boeing, SkyNRG	21.12.2011	Castor seed	One engine	Bangkok- Chiang Mai
Qantas	A330	Airbus	April 2012	Cooking Oil	50%	Sydney- Adelaide
ANA	B737 Dream-liner	Boeing	April 2012	Cooking Oil	10% blend	Evertt's Paine Field (KPAE) to Haneda Airport

(HND)						
Jetstar	A320	Airbus	April 2013	Cooking Oil	50% Blend	Melbourne - Hobart
Hainan Airlines	737-800	Boeing	March 2015	Cooking Oil	50% Blend	Shanghai to Beijing
Cathay Pacific	A350 -900	Airbus/ Amyris-Total	May 2016	Farnesane	10% Blend	Toulouse to Hong Kong
Europe and Middle East						
CARRIER	AIRCRAFT	PARTNERS	DATE	BIO-FUEL	BLEND	DESTINATION
QATAR Airlines	A340-600	Airbus, Shell	12.10.2009	Gas to Liquid (Not biofuel)	50% four-engine	London – Doha
KLM	B747-400	GE, Honeywell UOP	23.11.2009	Camelina	50% one engine	1.5 hours flight test
Iberia	A320	Airbus, Iberia, SkyNRG	03.10.2011	Camelina	25% of one engine	Madrid- Barcelona
KLM	B737-800	KLM, SyNRG	29.06.2011	Cooking oil	50% of one engine	Amsterdam – Paris
Finnair	A319	Airbus, SkyNRG	July 2011	Cooking Oil	50% Blend	Amsterdam- Helsinki
Air France	A321	Airbus, SkyNRG	October 2011	Used Cooking Oil	50% blend	Toulouse- Paris
Thompson Airways	B757-200	Boeing, SkyNRG	October 2011	Used Cooking Oil	50% blend	Birmingham Airport
Etihad Airways	B777-300ER	Boeing	Jan. 2012	Vegetable cooking oil	Fuel blend	Abu Dhabi – Seattle
Lufthansa	A321	Airbus, Lufthansa Technik (LHT) and MTU Aero Engines	15 July – 27 December 2011	Jatropha, Camelina, Animal Fat	50% of one engine	Frankfurt- Hamburg
KLM	B777-200ER	Boeing, SkyNRG	March 2013	Cooking Oil	50% blend	JFK, New York Weekly flight to Amsterdam (Total 26 flights)
KLM	A330-200	Airbus, SkyNRG, ITAKA	May 2014	Cooking Oil	20% Blend	Amsterdam – Caribbean Island (Aruba & Bonaire)
Finnair	A330	Airbus, SkyNRG, Statoil Aviation	September 2014	Cooking Oil	Fuel blend	Helsinki- New York
Lufthansa	A320	Amyris-Total	September 2014	Renewable Farsane- Sugarcane	10% blend (Max)	Frankfurt- Berlin
Lufthansa	Boeing and	6 group Airlines AirBP, Avinor	Jan 2016	Renewable Fuel	Not mentione	Refuelling Tank at Oslo Airport

	Airbus Fleet	SkyNRG			d %	(Lufthansa, Swiss, Austrian Airlines, Germanwings, Brussels Airlines)
The Americas						
CARRIER	AIRCRAFT	PARTNERS	DATE	BIO-FUEL	BLEND	DESTINATION
Continental	B 737-800	Boeing, GE Aviation, CFM, Honeywell UOP	7.01.2009	Algae and Jatropa	50% one engine	Houston- over the Gulf of Mexico
United	A319	Rentech	30.04.2010	GTL	40% two engine	90 minute flight test
TAM	A320	Airbus , CFM	23.11.2010	Jatropa	50%	45 minutes flight test
Interjet	A320	CFM, Safran, EADS,	1.04.2011	Jatropa,	50%	Mexico City- Tuxtla Gutierrez
BOEING	747-8F	Boeing new model aircraft	June 2011	Camelina	15% mix all four engines	Paris Airshow
Aeromexico	B777-200	Boeing, ASA	August 2011	Jatropa	30% blend	Mexico- Madrid
Continental	B737-800	Boeing, Solazyme	November 2011	Algae	40% blend	George Bush Intercontinental Airport t- O'Hare Chicago Airport
Alaska Airlines		Boeing, Bombardier, SkyNRG	November 2011	Used Cooking Oil	20% blend	Seattle – Washington
LAN	A320	SkyNRG, Air BP Copec	March 2012	Used cooking oil (SkyNRG)	Fuel blend	Santiago – Concepcion, Chile
Aeromexico	B777	Boeing, Honeywell Green Jet,	June 2012	Jatropa, Camelina	50% blend	Mexico City- Sao Paulo Rio + 20
GOL	B737	Boeing, Honeywell Green Jet,	June 2012	Cooking oil, Inedible Corn Oil	50% blend	Sao Paulo – Rio Janeiro Rio + 20
Air Canada	A319	SkyNRG	June 2012	Used cooking oil (SkyNRG)	50% blend	Toronto – Mexico City
LAN	A320	Airbus, LATAM Airlines, Terpel	August 2013	Camelina	20% Blend	Bagota- Calli
GOL	B737 Fleet	Boeing, Inter American Bank, Amyris, Total	July 2014	Renewable Farsane- Derived Sugarcane	10% Blend	Orlando- Sao Paulo (World Cup carrier)
United Airlines	Flight 708	AltAir Paramount	March 2016	3 years schedule flight non-edible natural oils and agricultural wastes		LA to San Francisco

2.5 Current energy used in aircraft engine

(Report analysis on Biojet fuel case studies on Air New Zealand, Continental Airlines, and Japan Airlines)

The future base of aviation fuel research conducted by Maurice et al., 2001 described chemical and physical characteristics of the fuel and reviewed the contents of its requirements, which included heat content, fluidity, corrosion protection, and stability.

It had been a continuation of the test by Bio Spk that blended for Jatropa- Jet A-1, Jatropa/Algae, Jet A and Camelina/Jatropa – Algae/Jet A. The detailed results for Composition, Volatility, Fluidity, Combustion, Thermal stability, and contaminants are depicted in Table 1 from the Evaluation BioSPk report 2009 (Bio-SPK, 2009; Jain, & Sharma, 2011). Details study will be conducted in chapter 4 and chapter five in the relationship to aircraft maintenance will be based on this evaluation from BioSpK report, as in [Table 3](#).

Table 3: Evaluation BioSPk report (2009) for different types of biomass versus traditional jet fuel

Table 1: Properties summary of Jatropa, Algae, and Camelina against existing jet fuel specifications				
Property	Jet A-1	A/Jet Jatropa	Jatropa/Algae	Camelina/Jatropa/Algae
COMPOSITION				
Acidity, total mg KOH/g				
Aromatics	0.10	0.002	0.001	0.003
1. Aromatics, volume%	25	0.0	0.0	
2. Aromatics, volume%	26.5	0	0	0
Sulphur, mercaptan, mass%	0.003	<0.0001	<0.0001	<0.0001
Sulphur, total mass%	0.30	<0.0001	<0.0001	<0.0001
FLUIDITY				
Freezing point, °C	-40 Jet A	-57.00	-54.5	-63.5
Viscosity –20°C, mm ² /s	8	3.663	3.51	3.353
COMBUSTION				
Net heat of combustion, MJ/kg	42.8	44.3	44.2	44.2
Hydrogen content, mass %				
One of the following requirements shall be met:				
1. Smoke point, mm, or	25	0	0	0

2. Smoke point, mm, and	18	0	0	0
Naphthalene's, volume, %	3.0	<0.01	<0.01	<0.01
THERMAL STABILITY				
JFTOT (2.5h at control temperature)				
Temperature, °C	260	340	340	300
Tube deposits less than	3	1	1	1
CONTAMINANTS				
Existent gum, mg/100 mL	7	0	<1	<1

This research supported much more biofuel flight tests conducted in the past, and they proved that biojet fuel can be a drop-in fuel without any major modification to the engine (Law, 2012). The aromatics (a molecule with a carbon ring of unsaturated bonds) remain as an impediment (Agusdinata et al., 2012; Daggett et.al., 2007; Dufferwiel, 2011; Liu et al., 2013). Moreover, a research study in creating biojet fuel – Fischer Trop (FT) with Aromatics is currently in progress under the American Standard Testing Material (ASTM) D4060 (IATA, 2013) and recently being approved (IATA 2015).

Commercial aviation kerosene has a very demanding specification with tight limits for the elements contained in the fuel and strict levels of energy content, density, viscosity, flash and freeze points. From the beginning of the testing, the technical option was to produce biofuel with a high capacity of blending without changing the properties of the fluid, what in aeronautical terms is known as a *drop-in* fuel. In this way, the modification was needed neither in aircraft engine and systems nor the logistic supply system, delivery and emergency equipment at the airports.

On July 1, 2011, the American Society for Testing and Materials (ASTM International), the most recognised body of international standards, approved a biofuel specification based on Hydro-processed Esters and Fatty Acids (HEFA), with the number ASTM D7566 (ASTM, 2011). An overwhelming majority of today in service turbine engines can operate with a mix of up to 50% of this specification biofuel in the standard kerosene.

Having been overcome the technical feasibility problems, the main hurdles are in attracting investment for biofuels production and distribution and ensuring that the industry has access to this biofuel stock, at a price that is cost-competitive with using traditional jet fuel.

The industry has called on governments to assist potential biofuel suppliers in developing the necessary feedstock and refining systems – at least until the fledgeling industry has achieved the necessary critical mass (ATAG, 2011). From policymakers, the industry is looking for encouragement and the right set of legal, fiscal and policy responses to ensure this new energy stream can produce results as quickly as possible (ATAG, 2012).

The EU accepted the challenge of promoting biofuels on air transport energy consumption. In June 2011, the European Commission, Airbus and high-level representatives of the Aviation and Biofuel producers industries launched the private-public program European Advanced Biofuels Flightpath (EABF). The purpose of achieve 2 million tons of sustainable biofuels used in the EU civil aviation sector by the year 2020 (EU, 2011), now delayed to 2030. This action requires the work of every stakeholder to promote production, distribution, storage and use of sustainably produced and technically certified biofuel. For this, it is necessary to join forces in establishing appropriate and effective financial mechanisms to support the construction of industrial “first of a kind” advanced biofuel production plants.

The project actions focus on the following issues:

- Facilitate the development of standards for drop-in biofuels and their certification for use in commercial aircraft
- Work together with the full supply chain to further develop worldwide accepted sustainability certification frameworks
- Agree on biofuel take-off arrangements over a defined period and at a reasonable cost
- Promote appropriate public and private actions to ensure the market uptake of paraffinic biofuels by the aviation sector
- Establish financing structures to facilitate the realisation of 2G biofuel projects
- Accelerate targeted research and innovation for advanced biofuel technologies, and especially algae
- Take concrete actions to inform the European citizen of the benefits of replacing kerosene by certified sustainable biofuels

The working methods and governance will be the ones established in the Strategic Energy Technology Plan (SET-Plan) of the EU, approved on February 4, 2011. This initiative falls under the European Industrial Bioenergy Initiative (EIBI) included in SET-Plan.

EABF proposal selects three biofuel processes as main candidates for mixing with aviation kerosene:

- Synthetic Fischer-Tropsch (FT) kerosene, produced via lignocellulosic biomass gasification followed by gas cleaning and synthesis over appropriate catalysts, approved by ASTM D7566 for a 50% blend.
- Hydrogenated Vegetable Oils (HVO), based on triglycerides and fatty acids which can originate from plants oil, algae, and microbial oil. In the absence of technical restraints, market forces, and legislation is the main forces for oil and fat selection.
- Hydrogenated Pyrolysis Oils (HPO), based on pyrolysis oils from lignocellulosic biomass. Pyrolysis oils can be hydrotreated either in dedicated facilities or co-processed with petroleum oils in refineries.

A general discussion of the state of the art in different processes can be seen in the presentations of a Workshop held in Milan on June 18, 2012, under the title “Upstream R&D and Innovation for biofuels in aviation” (A.Bauen, Jo Howes, 2009). There were presentations on Fischer-Tropsch fuel chain, alcohol to biojet fuel, pyrolysis and hydrothermal, microbial oils, HVO, and algae.

The market for transport biofuel (EEA, 2013) can be split into two groups:

- First generation biofuels are commercially available, using dedicated feedstocks, such as sugar beet, oilseeds, and starch crops. Sugars in these crops are fermented to produce ethanol, while oil crops provide an oil that is transesterified to form fatty acid methyl ester. The resulting ethanol and biodiesel are then generally mixed with fossil-based liquid fuels
- Second generation biofuels are not yet commercially viable but are expected to play an increasing role in the coming decades. It uses mainly lignocellulosic feedstocks, e. g. Short rotation coppice, perennial grasses, forest residues and straw, but also some oil seeds not used for food, like jatropha or camelina.

Thermochemical or biochemical conversion can treat it. The biochemical route, being less mature, probably has a greater cost reduction potential than the thermo-chemical route, but here a wider range of synthetic fuels can be produced better to suit heavy truck, aviation and marine applications (Sims et al., 2010).

Currently, there are no commercial biomass-to-liquid plants, but several pre-commercial plants exist in Finland, Germany, Japan and the United States. Biochemical conversion involves pre-treatment of cellulosic biomass and enzymatically enhanced hydrolysis and subsequent fermentation to convert hemicellulose and sugar into ethanol. There are demonstration plants in the EU (Denmark, Spain, and Sweden) and Canada. Other countries such as Brazil, China, Germany, Japan and the United States are also developing such second generation ethanol technologies.

Some of other promising possibilities like algal oils (third generation biofuels) or direct conversion of sugars to hydrocarbon fuels are either very high-cost processes or are still in the early research phase, being unlikely of playing any significant role by 2020. The benefits of microalgal biofuel systems include the ability to site them on marginal land (~85 % of surface area of the Earth's land mass) and to utilise saline and wastewater streams (Stephens et al., 2010). It seems that new technologies, e.g. tubular PBRs shall enhance the production of microalgae feedstocks for various fuel productions along with CO₂ recycle for algae culture and thus reduce the pollution. More innovations are still needed for the development of technologies which reduce costs while increasing the yields. This can be realised successfully through a coherent, extensive, and well-funded R&D program (Singh and Gu, 2010). Reports suggest that microalgal oil production could be achieved at a future target cost of US\$50/bbl (Stephens et al., 2010).

The technical certification of aviation biofuels is coordinated among the US-based ASTM International and the UK DEF STAN organisation for Europe, producing identical specifications. FT fuels have been approved in ASTM D7566 Annex 1 and HVO fuels approval is in Annex 2, while HPO is still being tested. Similar provisions are contained in DEF STAN 91-91 Annex D. During the certification process intensive tests have been conducted both by

airframe and engine manufacturers. Demonstration flights performed so far by airlines confirmed that the blend of biofuels and kerosene is “fit for purpose.”

Since through the ASTM International approval process, certain types of bio-kerosene and blends with conventional kerosene are recognised as meeting the conventional jet fuel ASTM 1655 specification, the existing infrastructure (most importantly pipelines, but also trucks and ships) can be used both for transport to and for fuelling at the airport. Thus the supply and logistics of certified drop-in biofuels, whatever the blend, present no problem to the distributors in this respect.

Each one of the above mentioned three processes has a different cost structure. HVO requires a modest upfront capital investment, but production cost is highly dependent on vegetable oil feedstock prices, which can make up to 60-75% of the final product price. Ligno-cellulosic FT and HPO biofuels have relatively low raw material cost, but more expensive processes, requiring high initial investments that make a very expensive product at the beginning of the manufacturing operation. Hypothetically, the prices will get down to the scale of the production increases.

The price setting and the associated support policies need to take into account all the three main benefits of aviation biofuels (Ninni, 2010):

- a) Reduction of external emissions of greenhouse gases in order to reduce the climate change effect of aviation
- b) Security of supply in order to reduce and differentiate EU energy supply channels from abroad
- c) Improvement in rural income and conditions in order to reduce existing gaps within the EU and to create new outlets for farm production

All these benefits should be achieved complying with the sustainability criteria and without altering the balance of the EU internal market. There is little doubt that present technology can create a fuel that replicates standard aviation kerosene from sustainable alternative raw materials, but doing so in a cost-effective way and at the scale of the industry needs remains a formidable challenge. According to recent EU estimations, aviation biofuel may cost above 2,000 euros per tonne, against 700 euros per tonne of fossil kerosene at 2013 prices.

Obviously, the European airline industry could not afford to treble the price of an element representing between 30 and 35% of its total costs without losing competitiveness to other world areas airlines.

The consequences of the oil price decrease started in the last part of 2014 are unclear and strongly dependent on the dimension and duration of this trend. As the oil share in the airline operating cost diminishes, some relatively old aircraft get their useful lives prolonged, and their replacement by more fuel-efficient airliners is delayed. At the same time, the price gap between fossil fuel and biofuel increases, making more difficult the introduction of alternative fuels. There is no clear forecast of how long will take a future oil price recovery although most analysts believe on a lapse of four or five years before that happens. Another confusing element is the evolution of the US dollar exchange rate versus other currencies (IATA, 2015a, [Figure 11](#)).

Figure 11: Relative variation of US dollar and oil price values.

As nominal oil price is quoted in US dollars, the appreciation of USD means an increase in price for those operators receiving most of their revenues in other currencies.

This relative position may change as the oil becomes scarce and its price goes up, but some experts (Hind, 2014) suggest that feedstock prices are going up as well in not a very different way than oil, as it can be seen in [Figure 12](#).

Figure 12: Cost of Jet kerosene versus selected biofuel raw materials 1999-2014. Source: Index Mundi, (Hind, 2014)

It remains the evaluation of the three external effects above mentioned. The CO₂ reduction may be evaluated at first sight considering the European Emissions Trading System (ETS) that gives biofuels a zero emission factor. Then biofuel consumption is practically exempted of the emissions market. Burning a tonne of kerosene emits 3.16 tonne of CO₂ that, if replaced by biofuel, will not have to be compensated buying any emission allowance. Unfortunately, the low price of allowances would translate this into 25-euro savings at a price of 8 euros per emitted tonne. Present predictions for future CO₂ allowances price do not go much higher unless world States having ratified the International Framework Convention on Climate Change (IFCCC) agree on more strict rules in the future Conference of the Parties (COP) yearly meetings.

Aviation's climate impacts, however, extend beyond those of CO₂ alone and the impact of other climate forcing agents needs to be addressed (Dessens et al., 2014). The key is to ensure that a scientifically rigorous methodology is applied appropriately for the respective emissions effect on climate. As emissions released during flight are unlikely to change significantly when drop-in biofuels are substituted for Jet A, non-CO₂ climate impacts per flight will not show the same significant decrease as is seen in lifecycle CO₂ (Krammer et al., 2013).

Security of supply is more difficult to evaluate (Rye et al., 2010). Additional supplying sources may limit the price increase of the oil as more providers would enter the market and get up the competition level, but aviation kerosene is taking around 7% of the oil production, and the European part will be close to 2% of the total oil extraction, very low fraction to have an immediate price repercussion.

The same reasoning applies to the additional jobs and wealth created by local production. The total EU renewable energy target for transport increases crop area globally by 5.2 million hectares, the equivalent of 0.7% of the cultivated European surface (Pilzecker, 2011). The economic effect of this action will not be negligible, but it remains to be seen where to find fertile idle land that, by the way, is not a renewable resource. Expected biomass sources for the 2006-2020 periods can be seen in Figure 4 from that reference.

The present projections of the National Renewable Energy Action Plans (NREAPS), established by the Directive 2009/28/EC, forecast a 50% of the agricultural bioenergy in 2020 coming from farming (the so-called "energy crops") and the other 50% being obtained from agricultural waste and residues.

2.6 Aviation drop in biofuel - Requirements

Aviation fuel is very complex. There are a few characteristics that need to be followed and met to reach its specific qualities. In general, gas turbine fuel should have the following qualities (Roll Royce, 1996):

1. Be 'pumpable' and flows smoothly under all operating conditions.

2. Permits engine starting in all ground conditions and give satisfactory flight relighting characteristics.
3. Gives efficient combustion in all conditions.
4. Has high calorific value as possible.
5. Produces minimal harmful effects on the combustion system or the turbine blades.
6. Produces minimal corrosive effects on the fuel system components.
7. Provides adequate lubrication for the moving parts of the fuel system.
8. Reduces fire hazards to a minimum.

The jet fuel is a specialised type of petroleum-based fuel used to power aircraft. It is in general of a higher quality than fuels used in less critical applications, such as heating or road transport. The colour of Jet fuel is clear to straw and is a blend of hydrocarbons, whereby it is a product of refined petroleum that belongs to the middle distillate group. The picture of the distillation tower shows jet fuel is distilled out of crude oil, as shown in [Figure 13](#) (Multi Commodity Exchange, 2008).

Figure 13: Jet fuel distilled out of crude oil at around 200 – 250°C

Source: MCX India aviation turbine fuel

The primary function of jet fuel is to power an aircraft, and the energy content and combustion quality are the key points to fuel performance properties (Hileman et al., 2010).

Other significant performance properties are stability, lubricity, fluidity, volatility, non-corrosive, and cleanliness (Roll Royce, 2007).

Besides provided that a source of energy to power the aircraft, fuel be also used as a hydraulic fluid in engine control systems and a coolant for certain fuel system components. In maintaining the proper quality and specification of the bio-derived jet fuel, many bio flight and engine tests have already been conducted. As a result, an enhancement in the quality and lack of certain characteristics, such Aromatics, is being developed (IATA, 2013c).

Aviation fuel distribution system will compromise with several stages starting from oil refineries to the airport storage tanks, before refuelling process to the aircraft wing. Depending on what logistics is viable for the local area, either by trucks, railway wagon or by ships (tanker) for transoceanic routes and inland waterways. The distributors also will need to ready with intermediate storage tanks farm for longer routes. [\(Figure 14\)](#)

Figure 14: Aviation fuel distribution system.

One of the most crucial elements in developing the biojet fuel for aviation is to ensure the engine does not need any modification or simply as 'drop-in' fuel. The biofuel has been

approved by the engine manufacturer and aviation authorities. It is entirely compatible with conventional fuel. Given its higher energy density, slightly less of it is needed. The engines, however, do not need to be converted. The technical challenges will remain as the authority, biofuel producers, and researchers concerns as the research phase works are parallel to reliability and maintainability towards the engine itself.

More understanding of the chemical makeup of the combustion sections needs to be measured in giving the required performance, engine operation, and material compatibility. This 50/50 blend has been evaluated in many engine ground tests and flight tests for its fuel efficiencies and particulate matter. (Zschocke & Scheuermann, 2012) Before introducing the 100% biojet fuel to the aviation industries, many more tests and works are required.

The details of the government body that participated from 2006 until 2010 are portrayed in [Table 4](#) from all the references and sources that were reviewed, no similar research, was found. The second chapter builds a theoretical foundation from the resources mentioned. Hence, this chapter looks into the ‘research issues’ in depth before the further chapter is discussed.

Table 4: Various consortia for the biofuel development(IATA, 2013a, 2015; ITAKA, 2012)

Consortia and Research Initiatives
CAEP- ICAO – Committee on Aviation Environmental Protectionis, a technical committee of the ICAO Council, established in 1983. Assisted ICAO in formulating new policies and adopting new standards and Recommended Practices (SARPs) Relate to aircraft noise, emissions, and more generally to aviation environment impact.
2006- Commercial Aviation Alternative Fuels Initiative (CAAFI) was formed to promote the development of alternative jet fuel options that offer safety, cost, and environmental improvement, and energy resource and security for aviation.
2009- Sustainable Way for Alternative Fuels and Energy for Aviation (SWAFEA) is a study for the European Commission’s Directorate-General for Transport and Energy to investigate the feasibility and the impact of the use of alternative aviation fuels.
2010- Sustainable Bioenergy Research Project (SBRP) was launched to demonstrate the commercial viability of using integrated saltwater agriculture to provide biofuels for aviation.
2010- Brazilian Alliance for Aviation Biofuels (Aliança Brasileira para Biocombustíveis de Aviação – ABRABA) was formed to promote public and private initiatives to develop and certify sustainable biofuels for aviation.
2010- Sustainable Aviation Fuels Northwest was shaped to promote aviation biofuel development in the Pacific Northwest of the United States of America.

2010- Queensland Sustainable Aviation Fuel Initiative Currently the project is focused on techno-economic and lifecycle analyses of the production of sustainable aviation fuel from three different feed stocks (sugarcane, algae and the oil seeds of the Pongamia tree) as well as laboratory research on the conversion of sugar cane to advanced biofuel.
2011 - Leading German research institutes, companies in the air transport sector, and biofuel producers founded the Aviation Initiative for Renewable Energy in Germany (AIREG) on 8 June in Berlin.
2012- Initiative Towards Sustainable Kerosene For Aviation (ITAKA) is a collaborative project framed in the implementation of the European Union Policies, implementation of European Industrial Bioenergy Initiative (EIBI) and specifically aims to contribute to the fulfilment of some of the short-term 2015 EU Flight Path Objectives
2013 - Sustainable Aviation Biofuels for Brazil (SABB) project was to carry out a comprehensive assessment of challenges and opportunities for implementing an aviation biofuels industry in Brazil, taking into account technological, economic and sustainability aspects.
(2014-2018) BIOREFLY involves the industrial-scale demonstration of 2,000 t/y bio refinery processes to convert lignin to aviation fuel: -Validation at pre-commercial scale on novel competitive technologies for lignocellulosic-based aviation fuel production -Design, construction and operation of a first-of-a-kind paraffinic fuel industrial facility -Address the complete value chain, including the conversion of lignocellulosic energy crops and agro residues into biofuel -Test of jet fuel use in turbines and engines including demonstration flights, as steps towards ASTM validation
2015- Canada's Biojet Supply Chain Initiative (CBSCI) is to help enable carbon neutral growth in the Canadian aviation sector through the downstream integration of biojet fuel produced from certified sustainable, domestically produced oleo chemical feedstocks in a comingled airport fuel supply system.

2.7 Aviation and Environment

The growth of the aviation sector was proven by statistical data from the IATA annual report. About 2.3 billion passengers utilised air transport to move around the world, as it is the shortest and the fastest way of travelling in the years of 2009. Based on the future projections for air traffic, it has been presumed to increase at 4.8% per year till 2036 with the Asia/Pacific region to be the main contributor to this increment. (IATA, 2010b)

The growth of the industry is linked to increasing the total emissions that are produced by the aircraft engine, which contributes to climate change.

This literature review on interest in climate change by aviation has been brought up since the late 60s and in the early 70s (Kuhn, 1970). The beginning was triggered by the potential stratospheric ozone (O₃), which was highlighted by a supersonic aircraft (SMIC, 1971). Only later, the effects of nitrogen oxide were realised (Schumann, 1997; Friedl et al., 1997). The dramatically increased other research programmes to identify the emissions and their effects from aviation, other than those of CO₂, which might influence the climate, including

the emission of particles, the effects of contrails, and other aviation-induced cloudiness contrail.

[Figure 15](#) below show how Fossil fuel and Biojet fuel affected the emissions to Air, water, and Land in the same way. The outcomes obtained from the “forest to pump” LCA investigation are carried forward to combustion in a jet engine during an intercontinental passenger flight to provide a “forest-to-wake” analysis. (Eastin & Bowers, 2014) These results are associated with the same results obtained from the combustion of fossil fuel-based jet fuel.

Figure 15: Fossil fuel and Biojet fuel affected the emissions to Air, water, and Land

Due to that, Aviation is a concern in gathering full resources to sustainability in Biojet fuel as top urgency.

A second important target is the work of ICAO and its Member States with relevant organisations to strive to accomplish a mutual medium-term global aspirational goal, as to keep net global carbon emissions from 2020. Consideration of the particular circumstances

and the corresponding towards the capabilities of States, including developing countries; the maturity of air transport markets; the sustainable growth of international aviation industry. The emissions may increase due to the expected growth in international air traffic until lower emitting technologies and fuels, and other mitigating measures are developed and deployed.

This target of carbon neutral growth after 2020 is accepted by a number of aviation stakeholders (ATAG, 2011; IATA, 2011), and strongly depends on the utilisation of enough quantity of advanced biofuels, in addition to the participation of the other actions included in the four pillars policy. A schematic representation of the CO₂ emissions evolution can be seen in [Figure 16](#), showing clearly the prominent role attributed to biofuels in the task, after 2020.

Fig. 1. Long term targets for international aviation CO₂ emissions.

Figure 16: Long-term targets for international aviation CO₂ emissions.

Battle for the Skies

Airbus and Boeing are selling and building planes at a record pace. Net jet orders per year:

Note: net orders are net applied to year of original order.

Source: the companies.

The Wall Street Journal

Figure 17: Airbus and Boeing selling and building planes from 2004 - 2014.

The revolution of Airbus and Boeing, two leading aircraft manufacturers, has constantly been changing. Technological innovation in the aviation industry is comparable to that in current personal computers. Airbus and Boeing are selling and building planes with new technology and lighter material to increase fuel efficiencies (Wall, 2015). [Figure17.](#)

It has been acknowledged that since the 1970s, airplanes have become over 70% more efficient in their fuel use (Roll Royce, 1996). Since 1955 where 707-300 started the energy intensity to up 5.0 MJ/p-km to current latest technology Airbus 350 in the year 2015 for only 1.5 MJ/p-km (IATA Green Team, 2009; Lee et al., 2009) as can be seen in [figure 18](#).

Source: Lee, IATA

Figure 18: The fuel efficiency of new aircraft has improved from 1955- 2015.

According to (Amizadeh et al., 2016) trend changing on Boeing 737 classics to a new generation has contributed to increasing of the number of flights share, while the reduction in the share of the B757 and the practical disappearance of the MD80/MD90 series, both replaced by a mix of B737NG and A320 families. This fleet evolution collaborates to reduce CO₂ emissions per RTK, which can be seen in [figure 19](#).

Figure 19: Fleet evolution from 2004-2013 for single Aisle

All components of aircraft design from the engines to the tips of the wings are a testimony to increase innovation in the industry. Further discussion will concentrate on fuel revolution and aircraft maintenance operation.

2.8 Fuel Revolution

An alternative fuel that is produced using an (F-T) process has been certified for aviation usage by ASTM International Standard D7566 in September 2009 (ASTM, 2006). A 50% blend of (F-T) synthetic fuel with conventional fuels is currently used by a few biojet fuel flight tests for use in commercial aviation (IATA, 2009).

On July 1, 2011, the ASTM-approved the jet fuel product slate of Hydro-processed Esters and Fatty Acids (HEFA) under alternative fuel specification ASTM D7566 (IATA, 2013c). HEFA fuel that meets this standard can be mixed with conventional jet fuel, up to a blend ratio of 50% (Liu et al., 2013). HEFA is currently the leading process for producing renewable jet fuel and several airlines that have used this technology, including Aeroméxico, Air China, Air France, Finnair, Iberia, KLM, Lufthansa, and United (IATA Alternative Fuels, 2009; IATA, 2013).

An alternative energy of biojet fuel, which is clean and cheap, has become a concern of the aviation industry with high priority. The main problem encountered about land availability and sustainability mean that it is not prudent at this time to assume that in 2050, biofuels could account for more than 10% of global aviation fuel (Rosillo et al., 2012).

In January 2009, the involvement of Commercial Aviation Alternative Fuel Initiative (CAAFI), a research and development initiative involving various participants from Europe and the USA, moved towards an established effort of the US Air Force and an Airbus proposal that may possibly be brought together as a single Fuel Readiness Level (FRL) (CAAFI, 2009). This development is very intense as the legislation for the price, and potential new carbon emissions have effects for the fossil fuels. At the same time, the growing global demand for air travel has led to collectively motivated research to obtain more sustainable alternative fuels (Nair, & Paulose, 2014).

The biofuel is driven from many broad perspectives, as mentioned in the previous elaboration. The discussion continues as future exposure also needs to ensure the continuity of usage of the existing engine and infrastructure (Gegg et al., 2014). Engine maintenance needs to go parallel with this drive. The conclusion on the readiness level according to the ICAO environment report 2010 (ICAO, 2010) is shown in [Table 5](#) below.

Table 5: Fuel readiness level on the ICAO environment report (2010)

FRL	DESCRIPTION	TOLL GATE-progress updates
1,2	Basic Principles Observed and Reported Technology Concept Formulated	Biofuel technologies, including processes, were identified.
3,4	Proof of Concept Process validation	No agricultural land required for growth of feedstock (e.g. biofuels from algae or biofuels grown with water from low-carbon desalination) may develop to change this picture and be fully optimistic.
5,7	Preliminary Technical Evaluation - Fuel Approval	ASTM D7566 Approved
6	Full-Scale Technical Evaluation	Biofuel flight test/schedule flight conducted successfully since 2008.
8,9	Commercialization Validated Production Capability Established	International adaptation through methodology acceptance/technically feasible, and economically viable, e.g. full-scale operational- SkyNRG-KLM.

Remarks: The unclear and undergoing research if sufficient land and water will be available for growth of biofuels feedstock has given the need to grow food for a global population projected to increase from the current 6.7 billion to around 9.1 billion in 2050 (Jaeger & Egelkraut, 2011). This is where the FRL 3 and 4 need to be evaluated with the current policy. With all these concerns, it is not farsighted at this time to plan for high levels of biofuel penetration.

2.8.1 Biojet fuel overview- Biofuel generation

Many terms have often been used to identify the classification of biofuel; “first generation,” “second generation”, and even “third generation.” This is further divided into two groups: *conventional biofuels* (first generation) and *advanced biofuels* (second and third generations).

Conventional biofuels are ethanol obtained from starch, and also, oil crop-based biodiesel. This includes corn, wheat, sugar, soybean, and palm oil, which are also used as feedstock and production at commercial scale. This can be seen in [figure 20](#) below. Among all these three biofuel generations, the element that makes it different is the final product of the

biofuel and the maturity of science behind the fuel. Many types of research have already taken place and much more are still being developed. This is to make sure that this alternative biofuel can meet the supply and demand for future use. The advantages and the disadvantages lie behind the biomass itself, which determines the projection for its readiness level and to be in the global market.

Figure 20: Conventional and Advance Biofuel

Source: IATA 2008

2.8.2 Conventional fuel-First generation

The first generation biofuels are defined as those that are conventionally produced from food crops. Unfortunately, the first generation biofuels have been withdrawn due to many disadvantages. They were criticised for several reasons, such as relatively GHG emissions avoidance, unsustainable production related to deforestation, water use, land management, competition for food crop feedstock is pushing up food commodity prices, and the need for generous government support schemes to remain competitive even after the technologies have become mature. (ATAG, 2009) Also, some of the first-generation biofuels, such as biodiesel and ethanol which is produced from corn, are not suitable fuels for empowering commercial aircraft. Many of these fuels do not meet the high performance or safety

specifications for jet fuel. As a result, many hopes have been placed on the second-generation biofuels.

2.8.3 Advanced Biofuels

Advanced biofuels, also called as the second and the third generation biofuels, encompass biofuels produced from non-corn starch, sugar, or lignocellulose biomass, which reduce CI by 50% or more from a gasoline baseline. This includes cellulosic ethanol, a non-virgin oil-based biodiesel, and bio-synthetic gas. Conversion technologies for advanced biofuels have greater feedstock flexibility and product a neutral stance than conventional processes. Woody biomass, Brazilian sugar cane, and algae are commonly used as raw material (Sims et al., 2010).

The second generation biofuels produced via biomass and waste exploitation have significantly improved GHG emissions and carbon footprint, which have resulted in less environmental damage (Naik et al., 2010). Each of this generation was analysed and were identified for Air transportation use by giving the potential to deliver in large quantities, for greener, cleaner, and cheaper fuel. This can be categorised as *Jatropha* and *Camelina* for the short term feedstock while *algae* and *halophytes* as long-term feedstock (Noh & Zulkifli, 2012).

[Table 6](#) below gives the details of the first, the second, the third, and also the fourth generations biojet fuel and their sustainability (Awudu & Zhang, 2012).

Table 6: The sustainability in biofuel generation by Awudu and Zhang (2012)

Sustainability of in biofuel generation	1 st generation	2 nd /3 rd generation	4 th generation
Environmental benefit	Provide Initial breakthrough	Close to meeting Environmental benefit	Ongoing
Biodiversity	Negative impact	Lower conversion rate	Not relative known
Food Vs Energy	Higher food price competition	Lack of technological and research breakthrough	Technological and research still ongoing
Social and environment impact	Claimed to have both benefits	Benefits both	Initial thought, not proven

2.8.4 Short and long terms feedstock

To make the biofuel for aviation a reality, there must be a successful biofuel business plan. This can be done by selecting the right and efficient feedstock strategy, including the design flow process. Attention must be critical to the availability of the right feedstock at the right cost.

Jatropha Crucas

Jatropha is nonfood feedstock, whereby it can be a vast source of the aviation biojet fuel. Besides, it can be significant to the environmental benefit as it can offer demand without interfering with food crops or leading to deforestation. It can also be valuable as a multipurpose crop to avert degradation, desertification, and deforestation. (Nrel, 2008) The types of soil determine this short term feedstock productivity. For example, the fertile soil may lead to early fruiting; while with the contribution of organic matter sandy soil gives the best result of the production, and it is improper to plant in clay soil as it restricts the plant's growth (Akbar et al., 2009; Hashimoto et.al, 2014).

After it reaches the first harvest after eight months, it is considered to have full production (fifth year). Its lifespan is 60 years, which can still produce seeds for up to 50 years. With proper management control, the fruits can produce with high oil yield contents up to 60%. Researches are being done in experimental on the plant to obtain over 10 tonnes of oil per hectare per annum (10-15 kgs per tree accordingly to their maturity) as [figure 21](#).

Figure 21: Jatropha Crucas oil yields from the first to the fourth year. Source: IATA- Brazil jatropha

Camelina

Camelina or very often called camelina sativa, false flax or gold of pleasure, can be classified as an oilseed crop which is suitable for both food and non-food utilisation. This oilseed is also used in some parts of Europe as salad oil. It can be found in the Europe and the North of America. Camelina sativa is originated from Europe and is a member of the mustard family, along with broccoli, cabbage, and canola. Oil from Camelina can be converted to hydrocarbon green jet fuel that meets or exceeds all petroleum jet fuel specifications. (Berti et.al., 2011) With seed oil content in the range of 35-40% and even more (45%) in some genotypes, the fuel is a 'drop-in' replacement that is compatible with the existing fuel infrastructure, from storage and transportation to fleet aircraft technology.

One of the disadvantages of Camelina is its high level of resistance to plant diseases. In both experiments, complete resistant breeding lines were identified, and a continuous pattern of variation in disease incidence was observed, suggesting a horizontal type of resistance. (Berti et al., 2011) The first Airlines to use the refined Camelina as biojet fuel were the Japan Airlines in January 2009.

The biofuel component tested was a mixture of three second-generation biofuel feedstock: Camelina (84%), Jatropha (under 16%), and algae (under 1%). (Rizki, 2009) (International Air Transport Association, 2010) Like Jatropha, Camelina has certain limitations. The seeds are subtle (1000 seeds weigh about 1g) and therefore, require careful seedbed preparation before sowing to ensure proper crop emergence. Another issue is that there are no available herbicides for Camelina. However, this problem can be partially overcome by employing agricultural practices, such as a high seeding rate and appropriate sowing time. (Agusdinata et.al., 2012)

Halophytes

Accordingly to Glenn (2009), the most promising halophyte that has been found, thus far is *Salicornia bigelovii*. It is a leafless, succulent, annual salt-marsh plant that colonises new areas of mud flat through prolific seed production. The seeds contain high levels of oil (30 %) and protein (35 %), much like soybeans and other oilseed crops, and the salt content is less than 3%. According to (Glenn et al., 1998) A small drawback is that the seed contains saponins, bitter compounds that make the raw seeds inedible. These do not contaminate

the oil, but they can remain in the meal after oil extraction. During six years of field trials in Mexico, *Salicornia* produced an average annual crop of 1.7 kilogrammes per square meter of total biomass and 0.2 kilogrammes per square meter of the oilseed. These yields were equal or exceeded the yields of soybeans, and other oilseeds are grown using freshwater irrigation. (Bashan et.al., 2000)

Algae

Among all of the second generation biofuels, algae fuels have attracted the most attention and have more optimistic solutions. If we are to produce the same amount of algae-based fuel as we produce from the normal petroleum, the advantage is that the algae-based system would consume approximately 13% of Carbon dioxide of the production from Petroleum as [figure 22](#). (Fortier et al., 2014; Isa et al., 2010; Nair & Paulose, 2014; Satish Lele, 2011)

- Micro-algae is more efficient converters of solar energy than any known plants because they grow in suspension where they have unlimited access to water and more efficient access to CO₂ and dissolved nutrients.
- The total oil content in algae can be up to 70% of their dry weight.
- Micro-algae are the fastest growing photosynthesizing organisms. They can complete an entire growing cycle every few days.
- 120 tonnes of oil/hectare/year can be produced from algae.
- Algae production can be increased by increasing the carbon dioxide concentration in the water.

Figure 22: The Comparison of the Physical Properties Of Algae Biofuel And Fossil Fuel.

The [table 7](#) below summarises the short and long terms feedstock for the advantages and disadvantages.

Table 7: A summary of the short and long terms of biomass

SHORT TERM		LONG TERM	
JATHROPA	CAMELINA	ALGAE	HALOPHYTES
Non-foods crop	Non-foods crop.	Non-foods crop.	Non-foods crop.
30 to 40% oil from each mass of seed.	Minimal inputs.	15 times more oil/ square km than others.	High oil yield.
Grown in marginal land 2 to 3 years to get the effective yielding.	Cultivated in the marginal land as a rotational crop.	Grown in polluted/ salt water, desert barren land.	Grown in a barren land.
Residues are toxic for both human and animal fertiliser after treatment.	Animal feedstock.	Animal feedstock.	Residue can be used as animal feedstock.

2.8.5 Biofuel process methods

In the IATA Alternative Fuel Report (2010), the previous method has already been certified by the ASTM; FT in 2009 and HEFA in 2011. From the report, a few types of research have been conducted to certifying the new method, such as:

1. Alcohol to Jet system Paraffin Kerosene
2. Direct sugar to hydrocarbon
3. FT with aromatics
4. HDCJ- Hydro-processed Depolymerized Cellulosic Jet

With some processes mentioned, the most significant advantage that needs to be further developed is the simplest technology used. Besides, its benefits like low in cost and high in efficiency return reduce the cost of the fuel. Again, the characteristics of the jet fuel need to be looked into, as besides advantages, there are challenges as well, such as its lower heating value (LHV) and its high freezing point. Additionally, there is a concern on the properties of new biojet fuel on the compatibility of material through contamination, such as metals from the raw material (Alberici et al., 2014; Daggett et al., 2007).

CAAFI as aviation stakeholders concerned in bringing commercially viable, sustainable alternative jet fuels (SAJF) to the marketplace to help meet the sustainability goals of the jet-powered aviation community. The [table 8](#) showed the selected announced SAJF purchased agreements as November 2015 (IATA, 2015).

Table 8: Selected announced SAJF purchased agreements as November 2015

Aviation Purchaser	SAJF Producer	Amount
United	AltAir Biofuels	5 M gallons per year(GPY) for 3 years from 2015
Alaska Airlines	Hawaii Bioenergy	Undefined quantity
Cathay Pacific	Fulcrum Bioenergy	375 M gallons over 10 years
Southwest	Red Rock Biofuels	3 M GPY for 7 years from 2017
FedEx	Red Rock Biofuels	3 M GPY for 7 years from 2017
GE	D’Amcinoff Group	0.5 M GPY
Gulfstream	World Fuel Services	3 years supply agreement
United	Fulcrum Bioenergy	90-180 M PGY over 10 years
World Fuel Services	AltAir Biofuels	N/A

2.9 Biofuel and the impact on aircraft performance – BurnFAIR project.

ASTM D4054 was developed to provide the biofuel producer with a guide related to testing and procedures. The testing covered basic properties, compositions, and performance. It included tests that had been fit for the purpose of checking the properties, for example, engine test cell, and full-scale engine testing.

Since the first approval of alternative fuel for FT was in 2009, and HEFA in 2011 by ASTM, an increased commercial flight test, and schedule flight could be observed. Until June 2016, HEFA was used for more than 25 airlines, which included over 1,500 flights. Looking at this trend, it demonstrated the technical feasibility of these alternative fuels, and most importantly, it is the interest from the airlines.

Furthermore, in conducting the engine tests, one must meet the requirements that between 60, 000 and 225, 000 gallons of test fuel must be used to support the engine testing. The test is divided into two phases:

1. First, the Performance and the emissions tests are carried, which require shorter time.
2. Second, the endurance of the engine or the durability test requires longer time and more fuel volumes. This is further explained in detail in [Figure 23](#) below.

Figure 23: Honeywell HTF700 Engine Durability Test (Source: 2012 CRC Aviation Fuel Meeting Presentation, USDOT/RITA/Volpe May 2, 2012)

Performance during take-off and cruising

From the tests conducted, the historical engine data were examined and recorded. For example, a six-month study from Lufthansa Airlines that used biojet fuel demonstrated positive effect to the engine trend analysis. This study was part of the FAIR (Future Aircraft Project) Project, with the aim to gain in-service experience using biofuel. During another six-month study, which was known as the BurnFAIR Project, an engine (V2533) from the Lufthansa Airbus A321 (D-AIDG) was refuelled with a biofuel blend from 15th of July 2011 until 27th of December 2011 and performed 1,187 scheduled flights between Hamburg and Frankfurt. The biofuel blend was supplied by Nestle Oil that contained a mix of 50% biosynthetic kerosene and 50% conventional kerosene.

The results of this study demonstrate that there was an increase in the flight frequency (flying). In the project that was carried out by Lufthansa, the findings showed that Fuel Flow using the Biojet fuel was about one percent lower compared to normal conventional fuel (MTU Aero Engine, 2012). Moreover, observation of the engine trend analysis showed a reduction in fuel flow of 1.2%, which was due to higher fuel heating value from the biofuel blend. With consistent take-off and cruises, the fuel flow trends showed an average reduction in fuel consumption by 1.2% as the overall result of the projects. [Figure 24.](#)

Figure 24: BurnFAIR Engine trend monitoring results for Take-off and Cruise data

On the other hand, when fuel consumption was expressed in large quantities (tonnes), it showed one percent lower usage for this biofuel blend, and as a result, huge savings are achieved. The research also showed that the energy density of the biofuel blend was about one percent above the normal fuel when the fuel flowed through the fuel pump and was delivered to the combustion section, the energy produced had a similar efficiency (MTU Aero Engine, 2012), as shown in [Figure 24](#).

From Biojet fuel test conducted by Lufthansa in the year 2013, further engine performance data recorded by Lufthansa test cell equipment can be seen in [figure 25-27](#) below. The exhaust gases and particles have been measured via a probe in exhaust tunnel while the emissions measurement and analysis performed by DLR (German Aerospace Center) (Zschocke & Scheuermann, 2012)

Figure 25: CO₂ emissions result in 10% and 20% Farnesane with a reference to normal Kerosene

Figure 26: NO_x emissions result in 10% and 20% Farnesane with a reference to normal Kerosene

Reduction of No_x can clearly be seen for most power settings; however, the effect is weak and not completely consistent from one to another.

Figure 27: Soot emissions - number and diameter of particles result in 10% and 20% Farnesane with a reference to normal Kerosene

Slight different in the number of particles can be seen between 10% and 20% of Farnesane. Besides, the mean diameter is also not consistent, which might result of the agglomeration of particles travelling in long hoses used (Zschocke, 2015).

2.10 The current state of engine- Maintenance and Cost

Airlines around the world struggle with the cost of fuel, which at times has increased cost upwards of 30 %. (Raffi et al., 2002) Estimation of using 13% of biofuel in the future by the year 2020 should come as good news to airline industries (Safran & Snecma), 2012). In reality, airlines can be reassured that by using new alternative energy, they are not only saving their cost for fuel consumption, but also save the environment and energy, as well as increase fuel efficiencies. (James & Rahmes, 2009)

It is acknowledged that fuel, cost operation, and miscellaneous including aircraft maintenance are the Airlines operational cost breakdown In 2012, 46 airlines around the globe participated in the Maintenance Cost Task Force (MCTF) conducted by IATA. (Weselby, 2012)

Aircraft engine maintenance works in close collaboration with the engine manufacturer. The most expensive cost is for maintenance. All distribution costs for direct maintenance, as

presented by 46 Airlines in 2012, can be viewed in the annual report by Maintenance Cost Task Force (MCTF) by IATA, as in [figure 28](#).

Figure 28: Airline operational cost breakdown

The Maintenance Cost Executive of the year 2012 took a total of 4,104 aircraft, which was 625 from Boeing and 30% from Airbus, with narrow body aircraft represented 57%, wide body for 35%, and the remaining for turboprop and regional jets. From the annual MCTF report, the preliminary remarks ensured the importance of data quality and reporting of the operational data to be treatment using the standard IATA toolset and normalisation of the data based.

Direct Maintenance Cost by segment in the year of 2009 until 2013 can be seen in [figure 29](#).

Figure 29: Direct Maintenance Cost by segment in the year of 2009 until 2013 by IATA

With the data and analysis method carried out by MCTF, the results of determination of how much the cost had been for airlines spend to maintain its fleet and to be able to use it in the economic based measures for a new fleet or expansion. It is useful for the MCTF data were related to biojet fuel for future amendment.

As maintenance works in close cooperation with the engine manufacturer, the most important measure that needs to be revised when future biojet fuel is made a mandate is the engine contracts. An example of the scenario of aircraft engine contracts as [table 9](#) below; and details in [Appendix 1](#)

Table 9: Turbine Engine Manufacturer and Maintenance Programme

MANUFACTURER	MAINTENANCE PROGRAMME
ROLLS ROYCE-	TOTAL CARE
PRATT AND WHITNEY	JSSI
CFM -	TRU ENGINE
GE-	GOLD CARE
MTU	AERO ENGINE MAINTENANCE

“Maintenance agreements offer a method of smoothing these large peaks over a longer

period, allowing more predictable and efficient budgeting. Power-by-the-hour (PBTH) or Cost-per-flying-hour (CPFH) maintenance agreements offered by the manufacturers and MRO companies, now account for the majority of airline maintenance contracts. (Goetz & Graham, 2004)(GroupTransport Studies, 2008) (Roll Royce, 1996)

Examples include the Rolls Royce 'TotalCare' and General Electric 'OnPoint' engine packages, plus the recently launched Boeing 'GoldCare' air-transport-by-the-hour package for the new B787. In essence, PBTH contracts specify an agreed per-flight-hour price to maintain the airframe/engines for the predicted usage, based on the ratio of flight hours to cycles. The Operator would pay more if the agreed usage threshold exceeded (though this might be absorbed).

2.11 Biofuel and the impact in Maintenance Practice into existing fleet

Maintenance is the responsible of workers to the designer. The maintenance department needs to maintain the components or engine that is designed with references to guideline given and it needs to be parallel to the Aviation authorities. The designers (Manufacturer) inform the specifications of when what, and how to do it. Schedule maintenance is linked to the manufacturer and leads to the preparation of the individual airline job card. An example of schedule Maintenance programme development through Maintenance planning data can be shown as in [figure 30](#) below:

Figure 30: An example of B737 Classics Schedule Maintenance programme development
Source: Boeing

Airlines need to adapt to new energy, but an essential part is to ensure that the new energy can be used efficiently and is affordable to maintain. In this case, it is crucial for the Airlines to utilise new alternative energy with affordable maintenance cost to ensure that the engine systems can continually and safely perform its functions with reliability (Kinnison, 2004).

The Maintenance Review Board (MRB) would need to evaluate the changes in the maintenance programme to identify if the tasks need to be eliminated or reinstated. In some cases, the maintenance programme needs to be adjusted with the introduction of new elements to ensure its reliability and to conduct analysis in the event of system failure or components failure (Sundaram et al., 2011).

As general guidance, manufacturers provide Maintenance Planning Data (MPD) to operators as a current condition of the engine to develop an individual schedule maintenance programme. The normal condition and recommended schedule maintenance of the engine

are frequently updated by the engine manufacturer every six months or if any amendment or updates in the service bulletin.

Service Letters, Service Bulletins, and Airworthiness Directives (AD) must be going through by each operator and integrated into their plan where applicable. The Scheduled Maintenance Tasks should not be considered mandatory or all inclusive. This is when every single airline has a final responsibility to decide what and when to do it. Maintenance tasks need to be reviewed as recommended by OEM, engine, APU, and besides, vendor manuals should be considered as well.

Hence, airlines should incorporate additional tasks/task cards for those airplane items requiring special maintenance, lubrication, system/structural checks, which are based on maintenance experience, environmental, or other related conditions peculiar to each airline.

2.11.1 Operation

Twenty-five years of aircraft operation is considered its general lifetime. Between these years, an aircraft has to be maintained and modified as new technologies become available. The size and usage of aircraft, comparable to its fuel efficiencies in a relationship with long haul and medium haul, have a linear relationship to MRO (Morrell, 2009).

The MRO makes the transformation, whereby this requirement is needed in making sure that it can be maintained as new alternative fuels are introduced. In developing new sustainable biojet fuel to be used with the current aircraft engine, the main hurdle has been successfully overcome. First, the biomass researchers have realised the ASTM biofuel approval, and second, the drop in fuel into aircraft fuel tank without any modification to the aircraft system (Jain, & Sharma, 2011; Air Transport Action Group, 2009).

The development needs to be processed and focused in two different sets of scenario: time and goals. In term of time, more deliberate ideas can be developed when the process is focused on short, medium, and long terms. The adaptation new biojet fuel can be observed

through fuel trending via two methods: fuel flight test and schedule flight test. With these, more gaps can be bridged for current and future fuel, whereby the key output needs to be measured, and possible scenario can be captured. As for long term, the business assumption can be developed more precisely into MRO industries, whereby tools can be the leading key. This can be demonstrated in the adaptation of the elements of a featuring process for sustainable effectiveness (Lawler, 2011) as [table 10](#) below.

Table 10: Development process in operations time and goal adaptation

	Short term	Medium term	Long term
Adaptation to MRO for biojet fuel	Observation through biojet fuel trending through test and schedule flight testing	Developing the gap for future biojet fuel and current jet fuel.	Identifying the business assumption for new fuel and disaggregating the development and strategic aims.
Purpose	Identify adjustments to current strategic intent to optimise sustainable effectiveness.	Develop boundaries for next version of robust strategic intent	Identify business assumptions and develop a range of possible future strategic plans.
Key outputs	Operating decisions that change aggressiveness and differentiation	Identify capability investments	Identify potential capabilities to build team responses
Tools	Traditional environmental scanning tools, prediction markets, extreme strategizing	Ecosystem mapping base, best and worst case forecasts	Future scenarios
Who is involved	Top management -20 % Any boundary- spanner, current customers and relevant stakeholders	Top management 50%, Network and ecosystem community	Top management 30%, Board 75%, High-level government, NGO and community representatives, futurist
Number of scenarios	Zero, use goals instead	Three in current trajectory	Three of five scenarios of diverse conditions

2.12 General Maintenance scope

Maintenance is carried out by workers, as well as designers. The maintenance department needs to refer to the maintenance guideline given and parallel to the Aviation authorities while maintaining the components and engines designed.

During this check, the maintenance crew needs to check and record certain gaps and measurements for wear and tear (Preventive Maintenance). Preventive maintenance

activities include partial or complete overhauls, oil changes, lubrication, and so on at specified periods. Also, the maintenance crew will record equipment deterioration, so they know when to replace or when to repair worn parts before they cause any system failure.

The ideal preventive maintenance programme would prevent the occurrences of equipment failures. This programme includes tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring. *When new fuel is introduced*, long term recorded information is very crucial. This will be an indication in leading to any problems to unusual components defects.

2.12.1 Maintenance “check “– Schedule Maintenance

The check or inspect used to construe the meaning to a maintenance action requiring through examination of an item, components or structure for a general condition that is applicable. Normally, this is the focus directed to the following areas:

Proper attachment, safety wiring, cotter pins, fasteners, clamps, latches, tubing, plumbing, electrical wiring and connections, linkages, bearings, alignment, clearance, lubrication, obvious damage, cracks, delamination, fraying, operating pressures, fluid leakage, excess wear or play, corrosion, evidence of overheating, rubbing, aging, preservative coating or finish, cleanliness, and general appearance.

Also, this check does not require particular measurement, the removal of additional access panels or cycling of hatches/doors is not normally performed or removed in each check.

In correlation to Aircraft Fuel System Maintenance, the general maintenance classification can be described as two types: Preventive maintenance, which is also referred to as *schedule maintenance*, and the second type, *unscheduled Maintenance*.

Preventive Maintenance

The primary goal of maintenance is to avoid or mitigate the consequences of the failure of equipment. This may be best with the implementation of the new alternative energy-aviation biojet fuel by preventing the failure before it occurs, which Preventive Maintenance

and Condition Based Maintenance help to achieve. It is designed to preserve and restore equipment reliability by replacing worn components before they fail.

In biofuel case, more collections of data are needed on schedule flight for monitoring purpose. Preventive maintenance activities include part or complete overhauls at specified periods, oil changes, lubrication, and so on. During this check, the maintenance crew would need to check certain gaps and measurements for wear and tear to be recorded. This helps to project the biofuel to the next readiness level.

Also, with the proper record of equipment deterioration, the maintenance crew would know when to replace or to repair worn parts before they cause system failure. The ideal preventive maintenance programme would avoid all equipment failure before it happens. This includes tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring. When new fuel is introduced, long term recorded information is very crucial. This is an indication leading to any problem to unusual components defects.

As for other examples of preventive maintenance, fuel tank operators should determine sampling task intervals and based on their operating environment, fuel management resources, and in-service experience. In shaping towards new fuel, fuel sampling checks for microbial contamination task intervals should be based on airplane operating environment, fuel source reliability, and operator in-service. Previous experience with incidents of fuel tank microbial growth and/or resulting tank structural corrosion, should be taken as a high priority. Each operator should assess their fleet for the possibility of microbial growth corrosion, and then, plan and perform preventative maintenance to avoid costly corrosion damage.

Unscheduled Maintenance

Unscheduled maintenance includes all unexpected maintenance and accidents. Some scheduled maintenance may also be accomplished while an aircraft is down for unscheduled maintenance work. There are times of course when the system deteriorates rather rapidly

albeit in service achieving a low level of perfection. At other unfortunate times, the system breaks down completely.

In these cases, maintenance actions are necessary to restore the system to be more definitive, often requiring extensive testing, troubleshooting, adjusting, and very often, the replacement, restoration, or complete overhaul parts or subsystems. Since this breakdown occurs at various and unpredictable intervals, the maintenance actions are employed to correct the problem, and this is called or referred to as *unscheduled maintenance*.

2.13 Conceptual framework and hypothesis analysis

The problem with the aviation industry in creating sustainability and sustainable development is the need to address it as an ideology as a whole. If the core values represent a wrong idea, the aviation industry will lose in driving the effective changes on the target required. The transformation needs demands of new energy will compromise Airlines and the manufacturers to work as a team. In relation to aircraft maintenance, it is where, sustainability, maintainability, and reliability need to merge as one. This will engage to more open opinions within the leaders in the search for better solutions for the Aviation and biojet fuel.

2.13.1 Hypothesis Analysis

From the literature review conducted, five Hypothesis was formulated.

H1: Biojet fuel usage and adaptation to aircraft engine maintenance can be measured through its main concern, which is safety.

H2: If using biojet fuel, the cost of maintenance will be reducing.

H3: Policy between Engine manufacturer and the Airlines, including the government policy is not running in parallel, can create a huge hurdle in pushing the biojet fuel forward.

H4: Awareness among different department or Airlines on bio-jet fuel is low thus affecting the projection biojet fuel in near future to the environment concern.

H5: The biojet fuel implementation can be successful when time is the factor where it is affecting the adoption in biojet fuel

Five hypotheses were derived at in looking deeper to explore the relationships between the problems with the engine maintenance in aviation industries. This was done by looking into the safety issues, the cost, timing, awareness, and policy, as shown in [Figure 31](#) below:

Figure 31: Hypotheses in looking at the problem of safety, cost, timing, awareness and policy perspectives in sustainability approach.

2.13.2 Conceptual Framework

Figure 32: Bio jet fuel conceptual framework

The conceptual framework can best be described in this research as a theory of point and focus that was developed from the empirical observation and intuition to attack and support the overall conceptual research. From this conceptual framework, the direction of

this research investigation is clearly defined to the correct path for the starting point in the research problem and the establishment of the visions. The merging on every angle and aspect in the hypotheses will be taken into consideration in merging the biojet fuel, and maintenance is shown in [Figure 32](#) Every theory will be analysed in seeking the relationship.

2.14 Conclusion for Chapter 2

As a conclusion from this chapter, the state of the art of biojet fuel and its policy and maintenance has been viewed. The successful introduction of aviation biofuels will depend on the selection of the right support schemes in this case; at European level in order to promote the most efficient type of production in both environmental and economic terms. This does not disregard the possibility of reaching a biofuel production at a high scale that makes it more competitive with fossil fuels but it might take a period out of the 2020-2030 scenarios presently contemplated, and there is no indication that support schemes may become unneeded in the foreseeable future.

Figure 33: CAAFI- Targeting Cost Competitiveness

This [figure 33](#) from IATA fuel symposium relates the Technology in this research refer to Engine maintenance in leveraging full range for biofuel deployment in addressing the getting gap closer through Policy and incentives.

Figure 34: CAAFI Cooperative RDD & D efforts

CAAFI cooperative effort directly through Public and Private Partnership is leading the direction to a sustainable biofuel for Aviation sector. From Feedstock Production and Logistics, to fuel conversions and process to scale up, Fuel testing and approval to enabling the productions for the end user or buyers. It can be seen in [figure 34](#) above where every steps the support from the public, and private partnership will create a homogeneous relationship to support this efforts and imitative. (Sturtz et al., 2015)

From there, five hypothesis was developed and conceptual framework lead in heading the direction of the research.

INTENTIONALLY LEFT BLANK

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines the discussion on the research methodology for this study. According to previous studies, (Janic, 2002), the method for assessing the sustainability of air transport system has ruled out four dimensions of the system performance: operational, economic, social, and environmental.

Hence, this research methodology was adopted from these four dimensions and discussed them towards the relationship of Aircraft Maintenance, Repair, as shown in [figure 35](#) below.

Figure 35: Research Methodology

The discussion elaborates in detail the review of this new alternative energy that creates the sustainability mentioned and its urgencies, risks, and opportunities, whereby it can concentrate on the successful adaptation of MRO and its link to the incentive and mechanism to promote biofuel.

3.1 Research Objectives and Research Questions

As in section [1.3](#) with numerous sources and evidence on many issues, several objectives were formulated about the study:

- RO 1)** To critically review the issues concerning of usage biojet fuel for aviation.
- RO 2)** To identify the maintenance of aircraft engine in the usage of new energy (biojet fuel).
- RO 3)** To investigate the impact of air transport industries when using the biojet fuel.
- RO 4)** To identify the risk impact of the biojet fuel on aviation maintenance through maintenance visit in various departments.
- RO 5)** To discuss the implications of the biojet fuel used in commercial aviation in aircraft maintenance and economic review.

As in sections [1.4](#), the research questions are as below;

- RQ 1)** What is the relationship between biojet fuel and aircraft maintenance performance?
- RQ 2)** What are the impacts of biojet fuel to commercial aircraft maintenance and operations?
- RQ 3)** What are the risk factors that influence biojet fuel to aircraft maintenance?
- RQ 4)** What are the outcome of aircraft maintenance visit and economic from biojet fuel?"

3.2 Research design

In this research, it will refer to an overall action that is laid out in the research flow as [figure 36](#), to integrate the different components of the study in a coherent and the most logical way. To ensure the research question and research objectives in this study to be compiled throughout the data collection and data analysis.

RESEARCH FLOW

Figure 36: Research Flow

In this research flow, problem statement was first developed, and the further literature review was gathered at various time points from multiple sources. As such the reports from the authorities, namely, International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), Biofuel Organizations, as well as interviews with the Maintenance Department (Workshop, Base, and line maintenance). It is include two section discussed earlier. Details phase by phase has been developed as [figure 37](#) below.

Figure 37: Research Design

The fuel price is the worst enemy for Airlines, which is why Airlines need to decide what to change in reducing or managing it. Airlines cannot control the price of the fuel. However, they can use new engines with better fuel efficiencies. This research had focused its discussion towards the alternative energy to replace the current energy (fossil fuel) to save the environment, which is linked to maintenance and reducing the cost of Airlines.

From the methodology adapted from Harmsen (2006), the phases are briefly discussed from an overall aspect, starting from deciding until the delivery and define phase as in below:

3.2.1 The phase 1: Contents Analysis and Correlational

Phase 1

- Contents analysis
 - Report
 - Maintenance Manual
- Thematics Transcription and Analysis
- Results
- Research Questions 1
- Chapter 4

Phase 1 will try to answer the Research question 1;

“What is the relationship between biojet fuel and aircraft maintenance performance?”

This research included in-depth contents analysis through Biojet fuel report from the producers, authority (IATA, ICAO, FAA, CAA, EASA) to correlated to aircraft maintenance of 737-300/400 and engine maintenance manual of CFM 56 and components maintenance manual for the Fuel system. The report will be review and contents will be analysing, where details relevant correlation will be separated. The research element to investigate the questions raised in the problem statements, primarily targeted at the earlier stage to investigate the hypothesis as in [figure 38](#) below.

Figure 38: Multiple Resources in generating the content analysis correlation

Through developed an understanding from aircraft engineer and fuel approval holder, the evidence gathered were used to create details studies that reflected the experiences and the impact of each context in the adoption of the new technology. It also involved

preliminary data of the existing flight operation systems that had been already carried out in monitoring and quantifying the benefits of using the energy efficiency in all or one part.

The resources required to undertake such a feasible analysis are the study into the technological system requirements. Enhance regarding making it acceptable for the industry to adapt to the changes regarding input, processes, output, fields, programs, and procedures to gain information analysis from the existing flight test and the engine test stand.

3.2.2 The Phase 2: Preliminary Questionnaires Survey

3.2.2.1 Aim of Phase 2

The purpose of this phase 2 as a preliminary questionnaires survey is to provide a better understanding of the research to be a review. It can determine what needs to be the focus, how and where. The result from this Phase 1 can be used as a resource that needs to be an emphasis on the next Phase 3.

3.2.2.2 Research questions

Based on the problem statement, few research questions have been developed to ensure the research directions. In Phase 2, the research phase will answer the RQ number two:

“What are the impacts of biojet fuel to commercial aircraft maintenance and operations?”

3.2.2.3 Research flow and target

- Preliminary Questionnaires Survey
- 40 Respondents
- Aviation Personnel
- 4 sections
 - Section A - Demographic
 - Section B - General knowledge on biojet fuels
 - Section C - The feasibility of biojet fuels in aviation
 - Section D - Impact of the usage of biojet fuels

- Results and Analysis
- Research questions 3
- Chapter 5

In this research, it used exploratory questionnaires as the research methodology in conducting the evaluations in getting further understanding in the adaptation of biojet fuel to Aviation and maintenance specifically. [Appendix 2](#)

Exploratory questionnaires: These questionnaires based on exploratory studies where data collected is qualitative. A brief guide was introduced at the beginning of questionnaires, with open-ended questions, with appropriate probes/prompt listed under each section mentioned earlier.

According to (Bradburn et al., 1990) “the higher the need for control, the more critical it be that an interviewer is present and possibly that the questionnaire is done on paper”. The data that being collected in this phase 2 were straightforward data which been gathered in the previous phase 1 and the respondent were chosen on convenience – based.

There are nine steps involved (Bradburn et al., 1990) in the development of a questionnaire:

1. Decide the information required.
2. Define the target respondents.
3. Choose the method(s) of reaching your target respondents.
4. Decide on question content.
5. Develop the question wording.
6. Put questions into a meaningful order and format.
7. Check the length of the questionnaire.
8. Pre-test the questionnaire.
9. Develop the final survey form.

Examples on Section D questionnaires.

Section D: Impact of the usage of biojet fuels

Table 11: Example of questions Section D Impact of the usage of biojet fuel

No.	Question	Very High	High	Moderate	Low	Unsure
1	Better Environment	5	4	3	2	1
2	Better fuel cost	5	4	3	2	1
3	Increased engine performance	5	4	3	2	1
4	Saving Airlines for maintenance cost	5	4	3	2	1
5	Sustainable aviation industries can be achieve	5	4	3	2	1

The questionnaires design as Closed- Ended Questions. With these types, it is efficient; the response will be easy to interpret. Since this is only the preliminary questionnaires, the researcher does not intend to explore further the meaning of the responses at this phase. The Likert scales were used where five –point scale from very high to unsure.

3.2.3 The Phase 3: Data Collection and Analysis using Risk Assessment

3.2.3.1 Aim of phase 3

The purpose of this phase 3 is use as a details data collections in getting depth analysis on the impact of Biojet fuel to Aircraft engine maintenance. The determines objectives and scope from the area of maintenance and new energy to be introduced; significant risk can be assessed in identifying the core value. In ensuring the quality and efficiency, this phase 3 is a continuation data collection after preliminary questionnaires survey in phase 2.

3.2.3.2 Research Questions

Phase 3 will answer the RQ 3;

“What are the risk factors that influence biojet fuel adaptation to aircraft maintenance?”

3.2.3.3 Research subject and target

- Phase 3

- Semi-structured Interview
- 50 respondents
- Aviation Engineering and Maintenance Personal
- Data Interpretation (Risk Assessment)
- Results and Analysis (Research Question 3)
- Chapter 6

Semi-structured interviews are used in this phase 3. A guide is used to questions and topics that need to cover from result and analysis in phase 2. The questions are standardised to all respondent in getting the delve deeply into the adaptation of biojet fuel and aircraft maintenance. The examples of questions below indicate that the researcher will use to ensure that complete and consistent information was received across different interviews in various departments. A letter of consent also is given at the early stage of the interview as acceptance to the term for the interview. [\(Appendix 3\)](#)

Table 12: Target group in Engineering and Maintenance department.

Technical Services	Technical Record	Engine Workshop	Engine Maintenance Planning	Components Workshop
--------------------	------------------	-----------------	-----------------------------	---------------------

The question: Interviews questions

Q1 : Please state your full name, education background and working experience in E&M

Q2 : What are your roles and responsibilities in E&M?

Q3 : Did you aware of the alternative fuel? Moreover, Biojet fuel?

Q4 : Describe how biojet fuel might or might not reduce climate change and how can environmental concerns be addressed for current fuel specifications.

Q5 : What are some barriers for the organisation with regards to aviation fuel? Please explain.

Q6 : Do you think your company might transform traditional fuel to biojet fuel in near future? Describe your thought and what the expected outcome might be.

Q7 : What is your major concern in maintaining the engine using the biojet fuel?

Q8 : Which major concern do you think have high risk in the adaptation of biojet fuel in Aircraft engine maintenance? Can you name it in sequence?

In this phase 3, five participants with broader work scope covering both Maintenance and Fuel Department were chosen as the pilot study, who was not participants in the actual study. It is to determine the validity of the interview questions (Yin, 2009). From the pilot study participants determined the interview questions meet the purpose of the survey. Therefore, no changes were made to the interview questions. [Appendix 4.](#)

Pilot questions

PSQ1 : In your opinion, do you think these ten questions above will provide applicable information for the following purpose of the study: To study the changes that biojet fuel will have on the aircraft engine maintenance, which will be through the perception of aviation management?

PSQ2 : In your opinion, do you think any questions should be deleted or added to achieve the purpose of the study? If so, please explain in details, so necessary for the interviewer to adjust the interview document accordingly.

PSQ3 : In your opinion, do you think the objective of the research is clear and you understand what the questions are trying to achieve?

3.2.3.4 Risk assessment

The risk assessment will lead and demonstrate the abilities in any hazard identification, ability to categorise and evaluate risk(s). In the case of bio jet fuel, these abilities will allow a 'suitable and sufficient' risk assessment to be conducted in this company so it can plan, organise, lead and Airlines company can control the adaptation process to minimise the effects of risks.

Risk assessment giving the purpose to the knowledge generation linking specific risk agent with uncertain, but possible consequences (Lave 1987, Graham and Rohmberg 1996). The differences vary from each risk source to another will lead to different stages of risk assessment. Risk assessment has become sophisticated and powerful tools in coping with the potential harm of human actions or true even (Morgan, 1998). Hazard identification and estimation will divide adaptation from generic components of risk assessment, Exposure and vulnerability assessment, and risk estimation. According to (Koivisto et al., 2009), there

are no fixed rules on how a risk assessment should be carried out; general principles were followed as in [figure 39](#).

Figure 39: Five general steps to risk assessment

The intention to quantify these regarding volumes of data, trends and frequency of updating, had been to generate the readiness of how the adaptation of using this biojet fuel for Airlines as a priority in the future, and to look into the impact on the commercial aviation sector. These require the legal feasibility inputs to compare the proposed system of the policy among the stakeholder with the current legal requirements. Simultaneously, marketing and economic feasibilities requirements were undertaken to study the commercial viability of the new alternative energy via cost-effectiveness review.

The risk is identified with colour as below identification on risk classification.

1.	Insignificant
2.	Minor
3.	Moderate
4.	Major

Example on Impact Analysis will be transcribed in the table below;

Table 13: Table of Impact Analysis

IMPACT	Policy	Awareness	Time	Cost	Safety
Low					
Medium					
High					
Extreme					

3.2.4 Phase 4: Discussion on Key finding and Structured Interview validation.

3.2.4.1 Aim of phase 4

The purpose of Phase 4 is to identify major risk from the key finding in phase 3.

Through the identification, further discussion and validation through a series of structured Interview will impose.

3.2.4.2 Research question

Phase 4 will answer the research questions four;

“What are the outcome of aircraft maintenance visit and economic from biojet fuel?”

3.2.4.3 Research flow and target

- Phase 4
 - Structured Interview
 - 10 respondents
 - Professional License Aircraft Engineer
 - Thematic Analysis SPSS /Excel
 - Results (Research Questions 5)
 - Chapter 6

In this research Phase 4, the structured interview were used. With the structured interview, the researcher can control the questions with the fix and specific orders. Ten respondents will be asked identical questions in the same order. See [Appendix 6](#).

The questions asked were based on Phase 1, Phase 2 and Phase 3 results and Analysis. Structured interviews have several advantages over surveys including lower levels of item nonresponse and the ability for an interviewer to mitigate inappropriate responses (Fowler, 2002).

- **Section 1 (Demographic Information)**
- **Section 2 (Case studies from Bio-SpK)**
- **Section 3 (Based on Section 2- biojet fuel affect engine maintenance)**

Table 14: Section 2 (Case studies from Bio-SpK)

Case Studies	<p>A)</p> <ul style="list-style-type: none"> - Air New Zealand Boeing 747-400 Rolls-Royce RB211-524G - 50% jatropha - Climb to FL 350, Mach 0.84 accels & decels, windmill engine restarts, starter-assisted engine relights, simulated missed approach, suction feed test <p>B)</p> <ul style="list-style-type: none"> - Continental Airlines Boeing 737-800 CFM International CFM56-7B4 - 7.5% jatropha, 2.5% algae 42% camelina, - Climb to FL390, Mach 0.78, accels & decels, windmill engine restarts, starter- assisted engine relights, simulated missed approach, suction feed test <p>C)</p> <ul style="list-style-type: none"> - Japan Airlines Boeing 747-300 Pratt & Whitney JT9D-7R4G - 28% jatropha/algae - Climb to FL390, Mach 0.80, accels & decels, windmill engine restart, suction feed test. The only hydro-mechanical engine used for this series of flight tests.
---------------------	---

3.2.4.4 Storage Stability

Storage stability - water and biological growth. Aircraft containing no water is impossible. This saturation level of a normal jet fuel is in part per millions (ppm) that's equivalence of temperature in degrees Fahrenheit, 50 F [10c] which may contain 50ppm of dissolved water.

Results from the flight test on Air New Zealand 32.2 ppm, 34.0p.m. - Continental Airlines and 19.0 p.m.- Japan Airlines, using biomass from Camelina, Jatropha, and Algae. (James & Rahmes, 2009). When the temperature is tremendous cooled, this water droplet and fuel combine to form a frozen substance often call Gael 'or icing.(Roll Royce, 1996) In the current fuel usage, additives need to be subordinate for the anti-icing and anti-micro biocidal agents.

Figure 40: Water composition in Biofuel flight test compares with conventional Jet fuel

3.2.4.5 Composition

Figure 41: The composition of Jet A/Jet A-1 compared to Jatropa, Jatropa/Algae, and Camelina/Jatropa/Algae comparing with Aromatics.

Table 15: The composition of Jet A/Jet A-1 compared to Jatropa, Jatropa/Algae, and Camelina/Jatropa/Algae comparing with Aromatics, and Sulphur.

COMPOSITION				
	Jet A/Jet A-1	Jatropa	Jatropa/Algae	Camelina/Jatropa/Algae
Acidity, total mg KOH/g	0.10	0.002	0.001	0.002
Aromatics: one of the subsequent requirements shall be met				
1. Aromatics, volume%	25	8.8	9.2	8.9
2. Aromatics, volume%	26.5	0	0	0
Sulphur, mercaptan, mass%	0.003	0.0004	<0.0001	0.0003
Sulphur, total mass%	0.3	<0.015	<0.0001	0.0403

3.2.4.6 Thermal stability

According to (Dufferwiel, 2011) “the thermal stability of fuel is the ability of fuel to act as a heat sink without the creation of insoluble deposits”. In a jet engine, before combustion, the fuel is heated through various heat exchangers to remove heat from aircraft subsystems. This heat leads to the formation of insoluble deposits which can plug the narrow passageways found in the fuel systems and extreme cases, result in component failure.

(Khandelwal et al., 2014) The exact mechanism that leads to the creation of deposits is unknown, but it is widely attributed to the aromatic and heteroatomic species within the fuel (Jain & Sharma, 2011).

[Figure 42](#) below shows that with a temperature of 260 degrees for jet A/ jet A-1 fuel, the tube deposit monitoring appeared to be less than three units, while higher in most of the biojet fuels from different types of biomass with less than 1 unit (James, 2009).

Figure 42: Thermal stability of Jet A/Jet A-1 compared to Jatropa, Jatropa/Algae, and Camelina/Jatropha/Algae

Jatropa, Algae, Camelina, and a combination of all the three types proved to have less tube deposit, thus, create a significant reduction in deposition and fouling of fuel in control units and injectors. With consistent thermal stability that creates less tube deposit, the advantages lie in less maintenance, and therefore, reduces the maintenance and operating costs. In the carbon build up, or often called as coking, back pressure is created in the fuel manifolds, whereby it distorts the fuel nozzle spray pattern. In the perspective of maintenance, when the flame pattern changes, it causes metal fatigue that leads to high engine cycle fatigue (Boeing 737 Aircraft Maintenance Manual, 2000).

The combustion and the turbine sections will receive the most impact, and it might cause engine malfunction, and in severe cases, the turbine damage may lead to catastrophic engine failure (Wanyan et al., 2010). On the other hand, coke builds up along the manifold of the fuel system and can change the hydraulic pressure which reduces the performance of

fuel control unit (FCU). As maintenance is a deep concern; if the problem occurs even for once, maintenance check will be carried out with higher deployment cost.

Hence, in conjunction with the tests proven by Bio-SPK (James, 2009) in ASTM D 3241, the biojet fuel needs to maintain similar characteristics, where it can be added as a 'drop in fuel.' Prevention of the present coke needs to be reduced, as this can be seen clearly in Figure 6.

3.2.4.7 Combustion

Aircraft engines produce emissions that are similar to other emissions generated by fossil fuel combustion. (ICAO, 2016) This gas emission is released from the exhaust sections through the complete continuous process. The emissions from a normal Jet Fuel for Aviation are CO₂, H₂O, and soot that contribute directly to the environmental impacts, whereby these emissions are released directly into the upper troposphere and lower stratosphere (Ribeiro et al., 2007). Besides, the presence of sulphur oxide in the fuel can result in detrimental air quality effects, and this is a strong reason to enhance the environmental concern in air transportation (IATA, 2009a).

The particles mentioned creating a reduction in the engine performance, particularly in the combustion section itself. Besides, these particles are emitted in the internal surface and can potentially disrupt the air flow or clog the holes, in particular for the secondary airflow. Furthermore, these particles also can erode the engine components (Greg et al., 2006). Hence, engine maintenance by the Airlines, especially in cases of frequent defects, is upsetting the performance.

With biojet fuel, the combustion properties for the smoke point is less than zero, while Jet A/A-1 has more than the value of 15, with the net heat of 44.2 MJ/kg. [Figure 43](#) shows the smoke point, and naphthalene's volume of biojet fuel are zero or close to zero, compared to the conventional Jet A/Jet A-1. Thus, maintenance of engine and costs will be reduced with the use of new alternative energy from biomass, by looking at the trend on the combustion properties.

Figure 43 Combustion properties of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae

3.2.4.8 Contaminants

In Bio-SPK (2009) report, the sample was examined for the low level of impurities, which can lead to reducing in aircraft engine fuel performance. There's no any detectable amount of impurities occurs for the present of sulphur, nitrogen and oxygen compounds to the addition of 21 metals. Based on the report, the results of the analysis showed that there was no traceable amount of impurities. The results are indicated in the table below, and the samples were obtained from three major Airlines that had conducted biofuel flight tests in 2009 (James & Rahmes, 2009)

Figure 44: Contaminants in Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae

3.3 Trustworthiness

In qualitative research instruments, trustworthiness is for measuring reliability and validity (Streubert & Carpenter, 1999; Lincoln and Guba 1985).

Credibility: With credible finding activities that increase the probability findings can produce. With suggesting that credibility will be established through prolonged engagement with the subject matter or allowing participants to validate the report findings represent their experiences.

Dependability: Once one credibility has been firm, the questions will be asked: How dependable the results obtain.

Confirmability: Through an assessment trail, this study will illustrate as clearly as possible the evidence and said processes that have led to the conclusions.

Transferability: Will refers to the probability that the findings will have to mean to other similar situation. The information needs to have potential appliers need to make a decision on transferability. (Streubert & Carpenter, 1999)

3.4 Ethical

Before conducting any questionnaires or interview, the respondent will be hand over a letter of consent, see [Appendix 5](#). The ethical principles must be observed while conducting the research in an ethical way. The principle of autonomy, where self-determination right closure will be implies (Polit & Hungler, 1999). The participants have the right to participate and terminate their participation at any time. Particulars information about the nature of the study and the importance of the research.

3.5 Conclusion for Chapter 3

This chapter lay out how this research is conducted, the methods that will be used to collect the data including questionnaires, interview, and survey. The phase 1 will be using qualitative while Phase 2, 3 and 4 will be using (mix method) qualitative and quantitative, and the finding will be presented and discussed in chapter 4, 5, 6 and 7.

INTENTIONALLY LEFT BLANK

CHAPTER 4

RESULT AND ANALYSIS: PHASE 1 - CONTENT ANALYSIS OF BIOJET FUEL REPORT AND AIRCRAFT ENGINE MAINTENANCE.

4.0 Introduction

Content analysis is a method of analysing written, verbal or visual communication message (Colorado State University, 2016; Cole, 1998). It is also used for making replicable and valid inferences from data to their context, for the purpose of providing knowledge, a presentation of facts, new insights, and practical guide to action (Elo & Kyngäs, 2008). In this research, the relational analysis was conducted. It begins with the act of identifying concepts present in a given report. However, relational analysis seeks to go beyond presence by exploring the relationships between the concepts identified. Content analysis process will be divided into three phase; Preparation phase, Organising phase, and Reporting phase.

4.1. Preparation phase – CFM 56 Turbine Engine Fuel System and its relationship to biojet fuel Maintenance

Preparation phase will start with selecting the unit of analysis CFM 56 Turbine Engine and Biojet fuel report. Both Inductive and deductive approached were used. This can be seen in [figure 45 and table 16](#) below;

The Aircraft engine was using CFM 56 from aircraft Boeing 737-400, and the details data were using inductive approach; from Specific to General.

Figure 45: Content Analysis Inductive method

Table 16: Unit of analysis: Biojet fuel Report

Report Alternative Energy/ Biojet Fuel	
1.	ICAO Environment Report 2007
2.	ICAO Environment Report 2008
3.	ICAO Environment Report 2009
4.	ICAO Environment Report 2010
5.	ICAO Review: Sustainable Alternative Fuels for Aviation
6.	ICAO Aviation & Sustainability 2011
7.	ICAO Global Aviation and Our Sustainable Future 2012
8.	ICAO Flightpath to a Sustainable Future 2012
9.	ICAO and Aviation Emissions 2013
10.	IATA 2008 Report on Alternative Fuels
11.	IATA Sustainable Alternative Aviation Fuels Strategy 2014
12.	IATA 2010 Report on Alternative Fuel
13.	IATA ANNUAL REPORT 2009
14.	IATA 2009 Summary of Report on Alternative Fuels
15.	The IATA Technology Roadmap Report Third Edition 2009
16.	IATA Annual Report 2010
17.	IATA Summary of Report on Alternative Fuels 2010
18.	IATA 2011 Report on Alternative Fuels
19.	IATA 2012 Report on Alternative Fuels
20.	IATA 2013 Report on Alternative Fuels
21.	IATA 2013 Report on Alternative Fuels 8th edition Dec 2013
22.	IATA Fact Sheet: Alternative Fuels 2013
23.	IATA FACT SHEET: Fuel The global airline industry 's 2013
24.	IATA Overview of Alternative Jet Fuels in 2014
25.	IATA Sustainable Alternative Aviation Fuels Strategy 2014
26.	IATA Fact Sheet: Alternative Fuels 2015
27.	IATA Sustainable Aviation Fuel Roadmap 2015
28.	World Energy Outlook, International Energy Agency 2006
29.	Alternative Jet Fuels- Chevron Corporation 2006
30.	Aviation Fuels Technical Review – Chevron 2006
31.	Environment Report Boeing. (2008)
32.	Evaluation of Bio-Derived Synthetic Paraffinic Kerosenes (Bio-SPK) 2009
33.	CAAFI Aviation Alternate Fuels Roadmap Level 1 / Scenario 1 2010
34.	Airbus Alternative Fuels World Biofuels Market 2011
35.	Malaysian Airlines System Berhad annual report 2011
36.	Policy Brief July 2011 Biofuels: Aviation moving at a clip- Lufthansa 2011
37.	Technical Memorandum Project FAIR 2012
38.	Alternative Jet Fuels - Aircraft Component Deterioration and Wear Assessment Renewable Jet Fuels Must Be Drop-In Fuels 2012
39.	ASTM D4054 Users ' Guide - 2013
40.	IATA Maintenance Cost Conference – Fuel Burn vs. Maintenance Costs Breakdown – IATA Assessment

41.	Airline Maintenance Cost Executive Commentary 2010
42.	Airline Maintenance Cost Executive Commentary 2011
43.	Airline Maintenance Cost Executive Commentary 2012
44.	Engine Maintenance and Fuel Burn, IATA Maintenance Cost Conference Atlanta 17-18 October 2012
45.	Airline Maintenance Cost Executive Commentary 2013

Figure 46: Biojet fuel report from authority and Manufacturer

Unlike wise Biojet fuel, the deductive approaches were used from general to specific as in [figure 47](#) and [table 17](#). This can be utilised when previous knowledge operationalizes the structure of analysis, and the purpose of the study is theory testing. (Kyngas & Vanhanen)

Figure 47: Content Analysis Deductive method

Table 17: Unit of analysis: Maintenance Manual Related

Aircraft Maintenance Manual	
1.	Boeing 737-400
2.	CFM-56 Engine
3.	Turbine Fuel System Jeppesen, Glencoe
4.	Components Maintenance Manual
5.	Boeing 737-700 / 800 Flight Crew Operation Manual
6.	Aircraft fuel pumps chapter 9.19 Aerospace
7.	The Jet Engine 5th Edition

8.	Boeing 737-700 / 800 Flight Crew Operation Manual
9.	System Review On Aircraft Maintenance Manual B 737 AMM
10.	Gas turbine technology Jet Propulsion Power through the Ages - 2007
11.	Reliability - Centered Maintenance SAE 2002
12.	Innovative Cooperative Actions of Research & Development in EUROCONTROL Programme CARE INO III Dynamic Cost Indexing (Aircraft Maintenance & Delay)

Figure 48: Maintenance Manual related

In taking into consideration the functions and the best possibilities in creating a relationship for the Normal Jet Fuel vs. Biojet fuel, the Turbine Engine Fuel systems were studied.

4.2 Organizing Phase

Open Coding from the reports from IATA, ICAO, Biojet Fuel SpK, Burn FAIR project, IATA MCTF, and Chevron Corporation as in [figure 49](#).

Figure 49: Open coding from various reports

From section 2.2 in Literature review, Engine turbine fuel has few characteristics that need to be met as requirements.

For instance, the fuel needs to be pumpable and flows easily under all operating conditions. Taking an example of [figure 50](#) show a pump operation with a nominal capacity of 400 litres/minute pumping fuel into a tank, from which it is drawn at a rate of 13000 litres/hour or 217 litres/minutes. In this case, the primary function of the pump is “to supply fuel to the tank at not less than 13000 litres/hour”. (Karassik et al., 2001)

Any maintenance programme for the pump needs to ensure that its performance does not drop below 271 litres/minute. (Note that in seeking to make sure that the tank does not run dry, the maintenance programme does not try to ensure that the pump continues “to be able to supply water to the reservoir at not less than 400 litres/minute”).

The fuel pump, which was manufactured by Argo-Tech (CFM 56, 1995) contains a fuel filter and two stages: a centrifugal boost stage and a gear stage. The centrifugal stage provides pressurised fuel to maintain fuel flow through an external fuel heater and the fuel pump filter and also provides pressurised fuel to the gear stage (Cygnor, 1997). The crucial fuel flow needs to be maintained at the correct and precise amount to achieve an optimum pressure, especially when the characteristics of the fuel are modified.

The functions and the best possibilities in creating a relationship for the standard jet fuel vs. biojet fuel throughout the fuel pump are taken into consideration and discussed. Boeing 737 old series is said to be the best aircraft in learning the basic aircraft system due to its simplest maintenance compared with the others. One example of the main components is the fuel pump, which was manufactured by Argo-Tech (Woodward, 2005). It contains a fuel filter and two stages of a centrifugal boost stage and a gear stage.

From the centrifugal stage, pressurised fuel is provided to maintain fuel flow through an external fuel heater and the fuel pump filter to the gear stage. Day-to-day observation, particularly pumps that is on constant duty operation, needs to be monitored hourly, and daily inspections should be made on any irregularities in the functioning of the pump (Igor et al., 2008). When the characteristics of fuel are modified, the crucial fuel flow needs to be maintained to achieve the correct and precise amount of fuel at a proper pressure.

Figure 51: Specific gravity position setting in MEC requirements

4.3 Reporting Phase – A new Maintenance paradigm for Biojet fuel correlation

In Reliability Centered Maintenance (RCM), “an operating context statement for a physical asset typically includes a brief overall description of how it is to be used, where it is to be used, overall performance criteria governing issues such as output, throughput, safety, environmental integrity” (SAE, 2002). Besides, examples of maintainability through adaptation from maintenance Maxim number 1 as in Table 18, (Moubray, 1995). Whereby the main engine fuel pump is analysed in reference to the aircraft's maintenance manual and components/manufacture manual in a proper manner to monitor the time between change of components (Adler, & Gellman, 2012).

OLD = Maintenance is about preserving physical assets

NEW = Maintenance is about preserving the functions of assets

Table 18: Maintenance paradigm in RCM adaptation from (SAE, 2002)(Moubray, 1995)

MAXIM		
Maxim 1	Maintenance is about preserving physical assets.	Maintenance is about preserving the functions of assets.
Maxim 2	Routine maintenance is about preventing failures.	Routine maintenance is about avoiding, reducing, or eliminating the consequences of failures.
Maxim 3	The primary objective of the maintenance function is to optimise plant availability at minimum cost.	Maintenance affects all aspects of business effectiveness and risk - safety, environmental integrity, energy efficiency, product quality, and customer service, not just plant availability and cost.
Maxim 6	There are three basic types of maintenance: - predictive - preventive - corrective	There are four basic types of maintenance: - predictive - preventive - corrective - detective
Maxim 8	If both are technically appropriate, fixed interval overhauls/ replacements are usually both cheaper and more efficient than condition-based maintenance.	If both are technically appropriate, condition-based maintenance is nearly always both cheaper and more effective for fixed interval overhauls/replacements throughout the life of the asset.
Maxim 10	The quickest and surest way to improve the performance of an existing “unreliable” asset is to upgrade the design.	It is nearly always more cost-effective to try to improve the performance of an unreliable asset by improving the way it is operated and maintained, and only to review the design if this cannot deliver the required performance.
Maxim 12	Maintenance policies should be formulated by managers and maintenance schedules drawn up by suitably qualified specialists or external contractors (a top-down approach).	Maintenance policies should be made by the people closest to the assets. The role of management is to provide the tools to help them carry out the right decisions and to ensure that the decisions are sensible and defensible.
Maxim 13	The maintenance department on its own can develop a successful, lasting maintenance programme.	A successful, lasting maintenance programme can only be drawn up by maintainers and users of the assets working together.
Maxim 14	Equipment manufacturers are in the best position to develop maintenance programmes for a new property.	Equipment manufacturers can only play a limited (but still important) role in developing maintenance programmes for new assets.
Maxim 15	It is possible to find a quick, one-shot solution to all our maintenance effectiveness problems.	Maintenance problems are best solved in two stages: (1) change the way people think, and (2) get them to apply their changed thought processes to technical/ process problems - one step at a time.

Turbine engine fuel systems need to supply a proper amount of fuel at the right pressure to its components, as shown in [Table 19](#). It also requires a few additional components because of the fuel used. Additional components are also found in the systems, such as Fuel heater, fuel dumping system, and warning annunciators system for low fuel quantity (Boeing 737 Aircraft Maintenance Manual, 2000). Correlation of biojet fuel characteristics and traditional fuel systems can be established, as components with functions have a linear relationship with the current maintenance practices.

Table 19: Components, Functions and its relationship to aircraft engine maintenance

COMPONENTS	FUNCTIONS	Relation to biojet fuel Maintenance
FUEL TANK	The fuel tank located in both wing and centre of the fuselage. It holds the fuel for power demand from the engine.	Inspection of the tank needs to be evaluated for any seals property damage and microbiological growth corrosions that will lead to a leak, cracking or pump blockage due to lack of AROMATICS- substantial to add additives.
ENGINE FUEL PUMP/ ELECTRIC BOOSTER PUMP	The fuel pump is located on the accessory gearbox (AGB). The fuel pump pressurises and circulates fuel within the fuel for fuel combustion.	The fuel flow needs to be tested for the minimum requirement of flow rate (literally low for Biojet fuel).
FUEL FILTER	The fuel filter is located in the lower section of the fuel pump, and its corrugated construction is designed to retain foreign particles suspended in the fuel, and prevent blockage their entry into the MEC.	Normal sediment possibility comes from the tank or the biomass residue.
FUEL NOZZLES	Fuel nozzles are installed into the combustion case and are connected to a fuel manifold and drain manifold.	Results from the decreasing fuel flow rate led to a decrease in Fuel Nozzle supply, which enhances disturbance on complete combustion.
PMC	Power Management Control, which provides an electronic Adjustment of the MEC to obtain optimum power settings for take-off, climb, and cruise flight conditions without constant adjustment of the thrust lever by the flight crew.	Detailed data on new fuel enhance the change in the details. The specific gravity of the MEC position.
MEC	Designed to control fuel flow variable bypass valve (VBV) position and variable stator vane (VSV) position on the engine. The MEC schedules the proper amount of fuel during acceleration and deceleration and regulates flow during steady-state operation to maintain a set core engine speed.	The specific requirements of fuel need to be met and adjusted accordingly.

4.4 Conclusion for Chapter 4

From the report and the maintenance manual content analysis, the conclusion of Chapter 4 can be summarised as in [figure 52](#) below. Technology adaptation in Alternative fuel will lead to the maintainability of the Engine when details evaluation to engine fuel system components and part being measured. Key issues in the context mentioned by RCM will be further discussed in chapter 5. Those are included the question of risk must be considered in more detail on;

- Environmental Integrity
- Safety
- Economy/Efficiency/Cost effectiveness/Incentive
- Time
- Awareness

Figure 52: Correlation from Biojet fuel into aircraft maintenance

INTENTIONALLY LEFT BLANK

CHAPTER 5

RESULTS AND ANALYSIS: PHASE 2 - PRELIMINARY QUESTIONNAIRES

5.0 Introduction

This questionnaires Phase 1 discusses the data analysis and findings from 40 questionnaires completed by individuals who are working in Aviation industries in the year of 2013 and 2014. All the respondents answered and completed all the questions helping the flow of this research to run smoothly.

The statistics from the questionnaires were statistically analysed. The IBM SPSS 21, Excel and google docs sheet program was used for the data analysis. The outcomes from findings are discussed according to the sections of the questionnaire.

5.1 Research Objective:

The purpose of this investigation is to carry out preliminary study in identifying;

1. The knowledge of biojet fuels among the aviation personnel.
2. The feasibility of biojet fuel is used in aviation.
3. The impact of using biojet fuel to aviation.

5.2 Research Methods:

Four sections of questionnaires has been hand out consist of;

- Section A: Personal (biographical) data
- Section B: General knowledge on biojet fuels
- Section C: The feasibility of biojet fuels in aviation
- Section D: Impact of the usage of biojet fuels

The targeted group was Aviation personnel whose has more than four years' experience in handling aircraft and more accurate towards Engine or Aircraft systems. The data was collected from various Aviation company included Malaysia, Saudi Arabia, Singapore. The

random sample of 40 participants provided an in-depth understanding of the general knowledge on alternative biofuel, the feasibility of biojet fuels in aviation and its impact. The selection process was identified through each participant's role in the use or testing of alternative fuel.

5.3 Research Results:

The result can be seen in all figure and table below. Details explanation can be concluded in discussions and analysis sections.

Section A: Demographics

5.3.1 Gender of Respondents

Table 20: Gender of Respondents

Gender	Frequency
Female	28
Male	12

Figure 53: Gender differences

Gender frequency of the participants in the study

Participants were asked to indicate their gender by placing a tick next to the relevant option provided (male or female). All 40 participants (100%) responded. Of the 28 respondents (70%) were male and 12 (30%) were female. Historically engineering has been a male dominated profession although more females are joining this profession in current trends.

5.3.2 Age Frequency, Position Frequency and Length Experience in Aviation Respondents

Table 21: Age of Respondents

Age	Frequency
20 - 25	3
26 - 30	6
30 - 35	7
35 – 40	9
40 - 45	5
45 – 50	6
50 – 55	7
55 – 60	4
60 - 65	2
Total	40

Table 22: Positions of Respondents in the Industry

Positions	Frequency
Aircraft Technician	5
Apprentice Engineer	3
Licensed Aircraft Engineer	17
Aviation Student	3
Aviation Lecturer	12
Total	40

Table 23: Length of experience in Aviation of Respondents

Length of experience in Aviation	Frequency
1 - 5 Years	6
6 - 10 Years	6
11 - 15 Years	4
16 – 20 Years	17
21 – 25 Years	4
26 – 30 Years	3
Total	40

Figure 54: Age Frequency, Position Frequency and Length of experience in Aviation of Respondents

Age varieties of the participants in the sample

Participants were asked to tick the age category. All the participants responded to the question (40 responses or 100%). The highest rate of 17% referring to age 35-40, while the lowest is at 5% at the age 60-65. The rate of 13% is sharing by age 30-35 and 40-45. At this age frequency, it is shown that every respondent has an experience more than five years in aviation industries, the position of respondents is shown in [Table 22](#) above.

Positions

Participants were asked to indicate their positions in the industry by writing the relevant answers. All 40 participants (100%) responded. The majority of the respondents, 17 respondents (43%) of the 40 respondents were License Aircraft Engineer from various Airlines. Other respondents are scattered in different positions such as Apprentice Engineers, Aircraft technicians, and Aviation lecturers and Aviation students where the lowest contribution by 7%. The Aviation students were chosen based on their final year currently on the Job training (OJT). Aviation lecturers were among those closer to industries and current new technology, with the contribution of 30% can create an excellent contribution to the study.

Length of years of service of the participants

The term of study or service was also tabulated, and respondents were asked to put the relevant numbers. Again, a 100% response rate was achieved (40 respondents). Six respondents (15%) of the 40 respondents having less than five years length of experience in the industry. While the majority of the respondents, 17 respondents (42%) reported having 16-20 years experiences in the aviation industry and other three respondents (8%) having 26 until 30 years of industry experience. This experience creating a tremendous impact on this study, as more experience the respondents have, the most contribution can be generated.

Section B: Personal Knowledge about biojet fuels in Aviation

Table 24: Personal Knowledge about biojet fuels in Aviation

Question	Very High	High	Moderate	Low	Very Low	Unsure
B1	1	5	20	8	5	1
B2	30	0	10	0	0	0
B3	2	8	20	2	3	5
B4	5	15	10	1	0	9
B5	4	6	20	0	0	10

Figure 55: Section B: Personal Knowledge about biojet fuels in Aviation

When addressing the question in this section B, its focuses in how good biojet fuels to the environment, to aircraft engines, and reducing fuel cost by using the biojet fuels. The questions (B1, B3, and B5) have the highest value of this section - Moderate by 50%. This is shown in [figure 55](#) that average respondents know about biojet fuel; it is used in aircraft and Airlines. With the second highest with 20%, the respondents have a very low knowledge in biojet fuel. Most of the respondents rated the second question until fourth question, (B2-B4) as very high.

The discussion below will be detailed on the individual question under personal knowledge about biojet fuels in Aviation.

B1: Do you know about biojet fuels usage in aviation?

Question	Very High	High	Moderate	Low	Very Low	Unsure
B1	1	5	20	8	5	1

Based on the survey conducted to answer the RQ1 the average of the B1 question is 2.65 it showed that majority of the respondents are moderately known about the biojet fuels usage in aviation. The knowledge about biojet fuels to the environment, to aircraft engines, and reducing fuel cost by using the biojet fuels need to be educated to all personals in aviation industries through training.

B2: Do you think biojet fuel is good to the environment?

Question	Very High	High	Moderate	Low	Very Low	Unsure
B2	30	0	10	0	0	0

The average of the respondent response to the knowledge on the environment is 4.50. It showed that the respondents were very highly agreed that biojet fuels are good for the environment.

B3: Do you think biojet fuel is good to aircraft engine?

Question	Very High	High	Moderate	Low	Very Low	Unsure
B3	2	8	20	2	3	5

Question B3 average is 2.73 that showed the respondents are moderately agreed that they think biojet fuel is good for an aircraft engine. This simply explained the knowledge on what biojet can do to aircraft engine was not relayed to the staff properly so that the knowledge is not enough for them.

B4: Do you think biojet fuel is good for reduced fuel cost?

Question	Very High	High	Moderate	Low	Very Low	Unsure
B4	5	15	10	1	0	9

The average for question B4 is 2.93 that showed the respondents are moderately agreed that they think biojet fuel is good for reduced fuel cost. The financial aspect was not being

shared to the respondent, but somehow they understood that the cost of biojet fuels as alternative fuels is much cheaper than currently used fuels.

B5: Rate your thought on how profitable biojet fuel to airlines/ aviation company?

Question	Very High	High	Moderate	Low	Very Low	Unsure
B5	4	6	20	0	0	10

The average for question B5 is 2.60 which is moderately knowledgeable on the profitable if using biojet fuels in aviation industries as alternative fuels. This due to the knowledge of cheaper alternative fuels that can be applied on most engines especially automotive vehicles.

Section C: The feasibility of biojet fuels in Aviation

Table 25: The feasibility of biojet fuels in Aviation

Question	Very High	High	Moderate	Low	Very Low	Unsure
C1	5	21	5	0	0	9
C2	6	5	24	1	3	1
C3	2	3	25	3	3	4
C4	3	3	24	5	1	4
C5	12	12	10	1	1	3

Figure 56: Section C: The feasibility of biojet fuels in Aviation

The first question (C1) probed if the biojet fuel is safe for the aviation industry. Most of the respondents agree with that statement only nine respondents (23%) are not sure. For the second question until fourth question, (C2, C3, and C4), the respondents averagely answered as moderate. The questions are more on the technical side if the biojet fuels will be used in aircraft engines. The questions asked about the modification is required to the engine if using biojet fuels, level adaptation to biojet fuel will be easier if that happened, and low technical feasibility changing from normal fuel (Jet A/Jet A-1 to biojet fuel) is needed. The last question (C5) however, they agree that biojet fuels will be widely used in future leaving three respondents unsure.

The discussion will be detailed on the individual question under feasibility of biojet fuels in Aviation.

C1: Biojet fuels are safe to be used in aviation.

Question	Very High	High	Moderate	Low	Very Low	Unsure
C1	5	21	5	0	0	9

The perception of the respondents on question C1 is averaging 3.10. This showed that the respondent moderately agreed that biojet fuels are safe.

C2: No modification required to the engine.

Question	Very High	High	Moderate	Low	Very Low	Unsure
C2	6	5	24	1	3	1

The average of the response from the respondents is 3.18. This is also showed the respondents were moderately belief that the engine required no modification before using biojet fuels.

C3: Level adaptation to biojet fuel will be easier

Question	Very High	High	Moderate	Low	Very Low	Unsure
C3	2	3	25	3	3	4

Question C3 is averaging at 2.65. The level of adaptation to biojet fuels will be easier is moderately accepted by the respondents.

C4: Low technical feasibility changing from normal fuel (Jet A/Jet A-1 to Biojet fuel)

Question	Very High	High	Moderate	Low	Very Low	Unsure
C4	3	3	24	5	1	4

The average for question C4 is 2.75 which moderately agreed by the respondents. The respondents agreed that there is low technical feasibility changing from normal fuel (Jet A/Jet A-1 to Biojet fuel)

C5: Biojet fuel will be used widely around the globe in the near future

Question	Very High	High	Moderate	Low	Very Low	Unsure
C5	12	12	10	1	1	3

The average for question C5 is 3.53. This showed that the respondents are almost highly agreed that Biojet fuel will be used widely around the globe in the near future.

Section D: Impact the usage of biojet fuels

Table 26: Questions (D1-D5) impact the usage of biojet fuels

Question	Very High	High	Moderate	Low	Very Low	Unsure
D1	13	15	8	1	1	2
D2	9	8	13	3	4	3
D3	5	6	22	2	3	2
D4	10	9	15	1	1	4
D5	5	10	17	3	2	3

Figure 57: Section D: Impact the usage of biojet fuels

[Table 26 and 27](#) identified the impact of biojet fuel usage. First question (D1) asked the respondents if biojet fuels lead to a better environment, most of them rated as very high and high. The second question (D2) asked if biojet fuels provide better fuel costs, the common answer is moderate. For questions (D3) and (D4), the respondents averagely answered as moderate. The questions are about biojet fuels will increase engine performance, and saving airlines fuel cost. Then the last questions (D5) asked if sustainable biojet fuels can be achieved. Most of the respondent rated as moderate. The detail questions were asked, and the respondent answer can be seen in the table below;

Table 27: The impact of the usage of biojet fuels.

No.	Question	Very High	High	Moderate	Low	Very low	Unsure
1	Better Environment	13	15	8	1	1	2
2	Better fuel cost	9	8	13	3	4	3
3	Increased engine performance	5	6	22	2	3	2
4	Saving Airlines for maintenance cost	10	9	15	1	1	4
5	Sustainable aviation industries can be achieve	5	10	17	3	2	3

Questions D1

Figure 58: Question D1 on better environment

The average for question D1 is 3.80. It showed that the respondents were highly agreed that using biojet fuels can give better environment.

Question D2

Figure 59: Question D2 on better fuel cost

The average for question D2 is 3.15. It showed that the respondents were moderately agreed that using biojet fuels can give better fuel cost.

Question D3

Figure 60: Question D3 on engine performance

The average for question D3 is 3.05. It showed that the respondents were moderately agreed that using biojet fuels can increase engine performance.

Question D4

Figure 61: Question D4 on Saving Airlines for maintenance cost

The average for question D4 is 3.35. It showed that the respondents were moderately agreed that using biojet fuels can save Airlines for maintenance cost.

Question D5

Figure 62: Question D5 Sustainable aviation industries

The average for question D5 is 3.10. It showed that the respondents were moderately agreed that using biojet fuels can sustain aviation. As the questions on section D, the impact

of using biojet fuel, from 40 respondents in the year 2013 and 2014, can be concluded as [figure 62](#) below;

Figure 63: The impact of using Biojet fuel based on 40 respondents

5.4 Discussions for Chapter 5

Questionnaires forms that have been conducted have been major contributors to this research. As preliminary data research, few important of conclusions can be made from this finding. It can conclude that the level of knowledge of new green technology, especially biojet fuels are still at a moderate level, among the personnel in the industry. Also from the [figure 63](#), it shows that biojet fuels knowledge is at 25% at the lower rate or unsure. Enhance the Airlines or Aviation personnel is aware and opened to the application of the biojet fuels in the aviation industry.

From this research, respondents aware that biojet fuels are safe to be used in aviation. This is because more than 25 Airlines already tested or conducted the biojet fuel flight as [table 22](#). Besides, biojet fuels release zero gas emission compared to current fossil fuels. Even more, safety and fuel quality specifications are of tremendous importance in the aviation sectors. The technical requirements for aviation biojet fuels are; a high-performance “ fuel (that can withstand a range of operational conditions)”, a fuel that does not compromise safety, a fuel that can directly substitute traditional jet fuel aviation, and also a fuel that

meets the required performance target. The feasibility of biojet fuel adaptation on Aviation industries is also giving results by 52% at the higher rate. (EBTP, 2009)

The research's questions on the impact caused by the usage of biofuels in can be supported to these questionnaires. As overall, the majority respondents acknowledge the good impact of using biojet fuels to the environment, safety and fuel cost. It is a big challenge facing the use of biojet fuels in aviation since it requires the high-quality standards requirements and also better impact on the environment as well as fuel cost. From literature data and the tests performed within SWAFEA, the use of alternative fuels such as the 50% SPK blends with Jet A-1 leads to significant reduction in engine soot and SO_x emissions due to the reduced content of aromatics and sulphur.

In improving the way of conducting this research, the interviews should be carried out on more appropriate targets and also in more details in the future. As stated earlier, the targeted respondents who are licensed aircraft engineers are one of the most significant respondents suitable to link the relationship of the biojet fuel when it comes to maintenance view. The target can be either fuel Department of airlines companies or engine manufacturers businesses or both. The fuel department is the one who manage the fuel consumption in an airlines company. Meanwhile, engine manufacturer is the one who decide what fuels can be used for their engine in the manuals. They are not included in these questionnaires due to their restriction and confidentialities; the permission has been denied.

As an overall conclusion, this researched questionnaires shows that awareness led to where the safety in biojet fuel usage is very crucial. The cost has a high impact when coming to new alternative fuel, as increasing in cost will create a huge hurdle to the Aviation industries. The policy is creating a medium resource that can lead to projection in the adoption of biofuel in aviation industries. From this questionnaires its objectives; as being a major contribution to the feasibility biojet fuels and its impact on the aviation industry in the context of Malaysian environment has been achieved.

INTENTIONALLY LEFT BLANK

CHAPTER 6

RESULTS AND ANALYSIS PHASE 3 & 4: BIOFUEL ADAPTATION IN AIRCRAFT ENGINEERING AND MAINTENANCE- A STUDY ON ITS RISK

6.0 Introduction

In this chapter, the further interview was conducted in continuation of the questionnaires carried out in chapter 5. In this stage, a semi-structured (Phase 3) and structured interview (Phase 4 will discuss in second part or the chapter 6) interview was carried out in analysing the risk of bio jet fuel adaptation at an Airlines Company. An objective of this research is to explore and develop the understanding on what risks to the Airlines for adaptation on the bio jet fuel especially in the area of Aircraft Maintenance Repair and Organisation (MRO). Concern on biojet fuel to increase the cost of maintenance while the current price remains high as demand is low remains uncertain. Research methodology being used is semi-structured interviewing personnel from various department and field work in understanding the place for biojet fuel in the maintenance flow. As results, details data from the interview can be concluded in presenting case study evidence in Airlines Maintenance and its risk assessment.

In reality, Airlines can be reassured that by using bio jet fuel is not only saving their cost for fuel consumption, but also, it is shown that this can successfully protect the environment, energy, and increased fuel efficiencies (Babikian & Lukachko, 2002). It is important not to overlook in the area of engine maintenance. Although fast progress has been made in making the bio jet fuel as another successful chapter in green energy, few significant issues remain unexplored.

The researcher believed, it is the best interest in understanding the risk in the Maintenance and Engineering department with correspondence towards adaptation in Biojet fuel. This interview will demonstrate and discuss the risk assessment on bio-jet fuel adaptation in the area of Airlines engineering and maintenance.

6.1 Problem Statement

Nowadays most of the Airlines are having a hard time to be sustained. Investment by applying new energy is demanding higher commitment especially in term of costing. The cost benefits of using bio jet fuel remain unclear; this is often taken to support the view why Airlines is hesitant and reluctant to invest and adopt this new fuel. Some aspects derived from the resistant required further investigation. A more promising approach would be through risk assessment. At the risk offending the reluctant, the risks classification, must be examined more carefully. (Noh et al., 2015) It does suggest that the other factors will be a balance that can be drawn between risk and opportunity. As an additional report from (IATA, 2014) on Alternative fuel, European countries and North America was the region that having the higher initiative development of the bio jet fuel followed by Asia Pacific.

6.2 Research Objectives

To aims and to strive for a competent preventive and practical maintenance system that is dependent, safe to use and cost effective, bio jet fuel need to study in depth for its adaptation. Therefore, the objectives of this research interviews are to identify and evaluate the risk referring to bio jet fuel adaptation in Airlines engineering and maintenance using the risk assessment systematic method.

6.3 Research Methodology- Structured Interview

Phase 3. A semi-structured Interview was used as a methodology for conducting the evaluations in getting further understanding the risk other than using the only questionnaire, which already been carried out in preliminary in phase 1.

Phase 4. Structured Interview was used to narrow down and validate the researcher results and analysis from Phase 1, Phase 2 and Phase 3. Broaden results and analysis can be generalized in this phase. Few respondents indicate a low level of understanding a questions or term in the questions, scripted explanation or defining the term as “based on your understanding” will be used to getting the feedback with a reasonable argument.

In this research Phase, before embarking on a details discussion of risk in biojet fuel adaptation in Airlines engineering and maintenance, the researcher found that it is important to compelling the theoretical framework for selecting the case. As Mintzberg (1979) noted: “No matter how small our sample or what our interest, we have always tried to go into organisations with a well-defined focus to collect specific kinds of data systematically.”

In this stage, the researcher wills elaborate details on the respondent feedback. The approach implemented in the study that involves acquiring an expert from the industries to form a line of reasoning to achieve the explanatory questions of (why and how), and providing reasonable and closure result. The interview protocol and guidelines have been followed as direct constructs to measured. When several of these constructs did emerge as related to the decision process, there were strong, triangulated measures on which emergent theory.

The interview was done through different departments, different level of positions and background in the Airliner. This latter distinction is creating a massive wall as the secretive information policy regards to environments and business actions that surround them will be very different and reflected the data collections.

6.4 Data Collections and Analysis – Phase 3

The risk assessment will lead and demonstrate the abilities in any hazard identification, ability to categorise and evaluate risk(s). (Subramaniam, 2010) In the case of bio jet fuel, these capabilities will allow a ‘suitable and sufficient’ risk assessment to be conducted in this company so it can plan, organise, lead and Airlines company can control the adaptation process to minimise the effects of risks.

Step 1: Identify the hazards

Hazards can be identified by asking around the Aviation personnel on something with a potential for bio jet fuel that can cause harm to the engine fleet. The risk is the likelihood of the potential of harm can be realized.

Step 2: Decide what might be harmed and how

Once identified several numbers of hazards, what might be harmed and how, will need to evaluate such as Engine Components and Engine Systems, Engine safety, and Engine schedule maintenance flow.

Step 3: Evaluate the risks and decide on control measures

After step 1 & 2, what can be prepared in protecting the Engine systems? Is the hazards can be avoided or remove entirely or the risks can be controlled so the adaptation will be likely.

Step 4: Record the findings

Identification of the risk and hazards result will be recorded, and plan for eliminating the risks and hazards will be taken.

Step 5: Reviewing the assessment and update as when necessary

Risks impact the adaptation on biojet fuel into aircraft engineering and maintenance. We can manage the transition by evaluating the risk management that comes from the decision and objectives. It can create negative consequences that lead to lengthening the process of adaptation.

6.5 Data risk evaluation

In understanding the risk occurs in adaptation on biojet fuel in the Airlines, the triangulation data from questionnaires in Phase 2, and Interview in this Phase 3 is discussed, and reports show in this sections. The respondents from various departments in Engineering and Maintenance can be classified as table below;

Table 28: Respondents from different Engineering and Maintenance Department

Department	Technical Services	Technical Record	Engine Workshop	Engine Maintenance Planning	Components Workshop
Respondents	5	5	5	10	5

Figure 64: Percentage of respondents from various Engineering and Maintenance Department

From the 30 respondents, data collections were gathered in proper documentation to identify the output. Different levels of respondent's understanding were collected, and risk measurement were the outcomes from various circumstances based on the perspectives which related to their work scope.

The data collections were based on common answered from the respondents. Safety, Cost, Policy, Awareness, and Time were gathered in the pilot study on one respondent in each department. The researcher using this guideline in projecting the question for interviews. The low-level risk indicates that the least answer as accordingly to Insignificant, where all respondents think it is not interrelated to their department. It does not have a severe impact on the adaptation of biojet fuel. However, the minor level of risk does not indicate an alarm for any risk, but it needs attention for the management to evaluate. The moderate risk level demonstrates that each of the department agrees that the time is an essential for the adaptation to flow. The high-risk level in this study shows the major indication of risk as it is critical information that can disrupt the transition to the adoption and it is a top priority.

The final level is the extreme risk rating. As aviation is a concern the highest priority is safety and it is a concern in all the departments which demonstrate 'safety' is identified as delivering the highest level of risk.

The questions used to measure the risk assessment among 30 respondents are;

The question

Interviews questions

- Q1 :** Please state your full name, education background and working experience in E&M
- Q2 :** What are your roles and responsibilities in E&M?
- Q3 :** Did you aware of the alternative fuel? Moreover, Biojet fuel?
- Q4 :** Describe how biojet fuel might or might not reduce climate change and how can environmental concerns be addressed for current fuel specifications.
- Q5 :** What are some barriers for the organisation with regards to aviation fuel? Please explain.
- Q6 :** Do you think your company might transform traditional fuel to biojet fuel in near future? Describe your thought and what the expected outcome might be.
- Q7 :** What is your major concern in maintaining the engine using the biojet fuel?
- Q8 :** Which major concern do you think have high risk in the adaptation of biojet fuel in Aircraft engine maintenance? Can you name it in sequence?

Pilot questions

- PSQ1 :** In your opinion, do you think these ten questions above will provide applicable information for the following purpose of the study: To study the changes that biojet fuel will have on the aircraft engine maintenance, which will be through the perception of aviation management?
- PSQ2 :** In your opinion, do you think any questions should be deleted or added to achieve the purpose of the study? If so, please explain in details, so necessary for the interviewer to adjust the interview document accordingly.
- PSQ3 :** In your opinion, do you think the objective of the research is clear and you understand what the questions are trying to achieve?

The outcome of the interview is presented in the table below:

The table below showed the number of respondents by category.

Department	Technical Services	Technical Record	Engine Workshop	Engine Maintenance Planning	Components Workshop
Respondents	5	5	5	10	5

Table below showed the Technical Services response on the questionnaires

Technical services	SAFETY	COST	TIME	AWARENESS	POLICY
R1	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	MAJOR
R2	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	INSIGNIFICANT
R3	MAJOR	MODERATE	INSIGNIFICANT	INSIGNIFICANT	MINOR
R4	MAJOR	MINOR	MODERATE	INSIGNIFICANT	INSIGNIFICANT
R5	MAJOR	MAJOR	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT

Based on the table the conclusion that can be made is that

Safety: Major
 Cost: Minor
 Time: Moderate
 Awareness: Insignificant
 Policy: Major

Table below showed the Technical Record response on the questionnaires

Technical record	SAFETY	COST	TIME	AWARENESS	POLICY
R1	MAJOR	MAJOR	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT
R2	MAJOR	MODERATE	MODERATE	MODERATE	INSIGNIFICANT
R3	MAJOR	MAJOR	MODERATE	MINOR	INSIGNIFICANT
R4	MAJOR	MAJOR	MODERATE	MINOR	INSIGNIFICANT
R5	MAJOR	MINOR	MODERATE	MINOR	INSIGNIFICANT

Based on the table the conclusion that can be made is that

Safety: Major
 Cost: Major
 Time: Moderate
 Awareness: Minor
 Policy: Insignificant

Table below showed the Engine Workshop response on the questionnaires

Engine Workshop	SAFETY	COST	TIME	AWARENESS	POLICY
R1	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	MAJOR
R2	MAJOR	MINOR	MODERATE	INSIGNIFICANT	MAJOR
R3	MAJOR	MODERATE	MODERATE	INSIGNIFICANT	MAJOR
R4	MAJOR	MAJOR	MAJOR	INSIGNIFICANT	MAJOR
R5	MAJOR	MAJOR	MINOR	INSIGNIFICANT	MAJOR

Based on the table the conclusion that can be made is that

Safety: Major
 Cost: Major
 Time: Moderate
 Awareness: Insignificant
 Policy: Major

Table below showed the Engine Maintenance Planning response on the questionnaires

Engine Maintenance Planning	SAFETY	COST	TIME	AWARENESS	POLICY
R1	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	MAJOR
R2	MAJOR	MINOR	MODERATE	INSIGNIFICANT	MAJOR
R3	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	MAJOR
R4	MAJOR	MAJOR	MAJOR	INSIGNIFICANT	MAJOR
R5	MAJOR	MODERATE	MINOR	INSIGNIFICANT	MAJOR
R6	MAJOR	MAJOR	MINOR	INSIGNIFICANT	MAJOR
R7	MAJOR	MAJOR	MINOR	MODERATE	MAJOR
R8	MAJOR	MAJOR	MODERATE	MODERATE	MAJOR
R9	MAJOR	INSIGNIFICANT	MODERATE	INSIGNIFICANT	MAJOR
R10	MAJOR	MINOR	MINOR	INSIGNIFICANT	MAJOR

Based on the table the conclusion that can be made is that

Safety: Major
 Cost: Major
 Time: Moderate
 Awareness: Insignificant
 Policy: Major

Table below showed the Components Workshop response on the questionnaires

Components Workshop	SAFETY	COST	TIME	AWARENESS	POLICY
R1	MAJOR	MINOR	MODERATE	MODERATE	MAJOR
R2	MAJOR	MAJOR	MODERATE	MODERATE	MAJOR
R3	MAJOR	MAJOR	MINOR	INSIGNIFICANT	MAJOR
R4	MAJOR	MODERATE	MODERATE	INSIGNIFICANT	MAJOR
R5	MAJOR	MAJOR	MODERATE	INSIGNIFICANT	MAJOR

Based on the table the conclusion that can be made is that

Safety: Major

Cost: Major

Time: Moderate

Awareness: Minor

Policy: Major

Table 29: Identification of Risk Classification from the interviews and questionnaires

Departments Risks	Technical Services	Technical Record	Engine Workshop	Engine Maintenance Planning	Components Workshop
safety	4	4	4	4	4
Cost	4	4	4	4	4
time	2	2	3	3	3
Awareness	1	2	1	1	1
Policy	1	4	4	4	4

1.	Insignificant
2.	Minor
3.	Moderate
4.	Major

Table 30: Risk assessment evaluation

CONSEQUENCES			Will effect in no or low exceptional circumstances	Will effect in low exceptional circumstances	Will effect in average, exceptional circumstances	Will effect in high exceptional circumstances
			Insignificant	Minor	Moderate	Major
PROBABILITY		LEVEL		2	3	4
Will effect in exceptional circumstances	Rare	1	1	2	3	4
Not likely to effect within the foreseeable future	Unlikely	2	2	4	6	8
May effect within the foreseeable future	Possible	3	3	6	9	12
Likely to occur in the foreseeable future	Likely	4	4	8	12	16

Table 31: Risk Assessment Matrix on Probability and Impact

Assessed Risk Level	Probability	Impact
Low 0-4	If effect were to occur, there would be little likelihood that damage/ malfunction will occur	Safety, Cost, Time, Awareness and Policy met within planned schedule and might have negligible impact.
Medium 5-8	If effect were to occur, there would be some changes that damage/ malfunction will occur and require rectification	Safety, Cost, Time, Awareness and Policy met within structured planned schedule and might have a minor impact.
High 9-12	If effect were to occur, it would be likely that damage/ malfunction will occur and require repairing	Safety, Cost, Time, Awareness and Policy impacts resulting in minor restructured planned schedule and might have substantial impact
Extreme 13-16	If effect were to occur, it would be likely that serious damage/ malfunction will occur and fatalities	Safety, Cost, Time, Awareness and Policy impacts resulting in major restructured planned schedule and might threatens the successful of the biofuel.

6.6 The risk and its impact

The risk and its impact as below;

Safety: The primary concern from the Airlines in every department. It is showed that the maturity of Biojet fuel still can be questionable. Aircraft maintenance and engineering will

ensure that the new fuel to be put in the engine will remain safe to all the components and safety. Besides, the engine contract between Airlines operators and Engine manufacturer will continue to be a top priority for the term and condition of the agreement need to be re-evaluated.

Cost: Cost will be a key element as a projection of the bio jet fuel will be economical once the supply and demand curve is a balance. At the moment, the bio jet fuel is way below the par of fossil fuel.

Policy: Due to the engine contract between Airlines operators and Engine manufacturer, the term and condition remain a top priority as the agreement will need to be reevaluated. The policy will also be involving the authority in certifying and ensuring the safety of the fuel supplier and the user (Airlines). It is also suggested that the incentive and mechanism to promote biofuel into civil aviation sector to be more effective.

Awareness: Mostly, all the departments have a very low awareness in bio jet fuel, whereby the reflections of the safety risk indicates Major rank. Due to the lack of awareness among the respondent, the deep interview cannot be conducted.

Time: The technology development in bio jet fuel for aviation which not all yet mature to be delivered to Aviation industries required time-consuming in ensures the successful roadmap of bio jet fuel. The Airlines response time is a moderate risk where it will be essential to the transition in reflecting the aircraft maintenance schedule.

From the interviews from various departments in Airlines, the data evaluation can be concluded from the table below;

Table 32: Risk Assessment Matrix on Impact and Probability analysis on Biojet fuel adaptation

IMPACT ASSESSMENT	Policy	Cost	Safety	Probability of risk occurring
Low	No impact on policy	No increase in total cost of engine maintenance	No impact on operational performance and to the adaptation of biofuel process	<10%
Medium	Small impact on internal policy milestone	Small increase in total cost of engine maintenance	Minor shortfall in operational performance, which might have a substantial impact on the adaptation of biofuel process	10-25%
High	Slightly bigger slip to key milestone of contractual policy importance	Significant increase in total cost of engine maintenance	Slightly major shortfall in operational performance, which impacts the adaptation of biofuel process	25-50%
Extreme	Large slip to key milestone of contractual policy importance	Large increase in threatens the viability of the adaptation of biofuel to the engine	Major shortfall in operational performance and to the adaptation of biofuel process	>50%

6.7 Analysis and discussion

We limited the scope of understanding the reason why Biojet fuel needs to impose in Malaysian Aviation industries. By undertaking this, more understanding into the impact of the shifting to the bio jet fuel will be an advantage. With this, it will provide staff and the aviation personnel with the awareness.

- Airlines have no authorities to proceed with the bio jet fuel projection by themselves unless the government policy is giving the full control of the amendment.
- The new alternative fuels will enable the engine contract to be null and void if a defect on the engine found due to new fuel usage.
- The question of how safety, Maintenance cost will be affected, need to be a top priority.
- Agreed in new alternatives fuels which create a significant reduction in energy consumption based on the Airlines authorities reports.
- If it is in future, 50% of current fuel being replaced and were to make this switch the entire fleet could reduce tonnes of carbon footprint.
- Awareness can be created throughout the Airlines operator in the countries in the agricultural sector as resources of the biomass energy investment.

Biojet fuel compatibility with an aircraft engine.

It is imperative to ensure, new fuel being introduced being compatible with the aircraft engine. Due to that fuel characteristics need to be fulfilled. Hence, in conjunction with the tests proven by Bio-SPK (James, 2009) in ASTM D 3241, the biojet fuel needs to maintain similar characteristics, where it can be added as a 'drop in fuel.'

6.8 Phase 4: Validation interview

6.8.1 Background Information:

This interview was conducted to validate the results from the previous interview and content analysis. To ensure the data is synchronised and be able to support the arguments, the more structured interview question was carried out in creating the adaptation of the biojet fuel to aircraft maintenance,

6.8.2 The purpose of this interview

1. To validate the results from the previous interview and content analysis.
2. To measure the correlation biojet fuel and aircraft engine maintenance

6.9 Phase 4 Data Collection:

In this section, the researcher identified the instruments, data collection, and data organisation techniques. The instruments were validated through a pilot study. The data collection was conducted using interviews. The data will be collected through e-mail, and in person. The structured online interviews were sent to that engineer whose work outside Malaysia such in the Middle East and Europe.

6.9.1 Research methods:

The formal interview and data analysis by SPSS and Excel were conducted were used to identify the lived experiences of participants regarding the impact that biojet fuel has in the aviation industry. The qualitative method is critical and interpretive, which can create change that is powerful, ethical, and communitarian (Denzin et al., 2006). The process involved open-ended, structured questions that resulted in the thematic analysis. The interviews were conducted by the target group below;

Engine Workshop	Engine	Maintenance	Components Workshop
	Planning		

The qualitative method utilised ten questions of every set interview concerning biojet fuels and how they may impact the airline industry. The data outlined alternative biofuel and environmental concerns within the aviation industry. Different target groups will have a different level of how their perception of biojet fuel and its overall impact. Another question was measuring the level of their awareness on biojet fuel as an alternate fuel neglected it can be profitable or not for the aviation industry. These questions were generated from previous results and analysis in phase 1, 2 and 3 and at the same time tried to capture the reasoning of each participant regarding the issues. From the interview, it is allowed further insight into how the outcomes will be affecting the adaptation of biojet fuel to the airline industry.

6.9.2 Research Design:

The research population included ten airlines personnel in a different level of departments and managements but having a licensed aircraft engineer is an obligation.

Population and Sampling:

Department	Line	Engine	Maintenance	Fuel	Engine
	Maintenance	Lecturer/management	Workshop		Maintenance
Respondents	3	5		1	1

The qualitative study provided a better understanding of what each participant believes about the future of aviation fuel. The qualitative study provided more in-depth information than a quantitative study. The sample size was projected to be ten participating employees from a combination of the department. Due to that, some respondents participated in Engine and maintenance lecturer and planning, which was enough to satisfy the purpose of the study and met the requirements of at least 10 participants for this doctoral study.

From Phase 3, the risks focused on the jet fuel characteristics and the requirements that were needed to be met by 'drop in fuel', whereby the complexity of aviation fuel was studied to ensure specific qualities and its relationship towards maintenance specification. Based on the economic analysis, the biojet fuel would create an opportunity for developing the new economy and new alliances. This, in turn, expands the business, and consequently,

creates more jobs in the most sustainable approach. To conclude, biojet fuel as renewable energy in the air transport should grow rapidly to support and sustain the industry.

The risks involved were reviewed by looking at the traditional jet fuel requirements in parallel to the characteristics of biojet fuel in the relationship of Maintenance point of view. This includes details on the characteristics of thermal stability, freezing point, viscosity, and combustion (Liu et al., 2013). Lastly, the opportunities were reviewed regarding the economic measurement of cost on maintenance with the priority in creating sustainability.

Table 33: Biojet fuel sustainable in four dimensions for Air Transport development on concentric circle adaptation in Aircraft MRO.

	Maintenance troubleshooting	Risks	Benefits of using biojet fuel
1. Thermal Stability	- Gums and particulates disrupt the fuel flow and clog fuel injection nozzles or small cooling holes in the combustor/turbine	-Increased maintenance	Less tube deposit with only 1% use of biomass -Reduced maintenance
2. Freezing point	-Pump needs to work hard at low freezing point, frequent bearing and seal inspection	- Increases in pump servicing -Increased time for engine turns around	-The freezing point can go low as - 63 ⁰ C
3. Viscosity	- Spray pattern from the fuel nozzles - Size of the droplets	Harder to relight at high altitude	- Lower viscosity with 3mm/s, compared to 8mm/s for Jet A/A-1 fuel
5. Combustion properties	-The particles emitted in the internal surface. - Disrupts the air flow or clogs the holes, especially the secondary airflow. - The particles can erode the engine components.	-High impact on engine maintenance cost. -Impact on reducing air quality (Sulphur oxide)	-With same net heat, it has less than zero smoke point, compared to traditional fuel that can go up to 25mm.

6.9.3 Ethical thesis

The researcher distributed consent forms that described the nature of the study and risks ([Appendix 6](#)). The participants were solely on voluntarily based and be able to withdraw from the study at any point, without recourse. There was no incentive provided for

participation. The data collected was kept secure and confidential. The findings did not include names or anything that could identify participants. All respondent material will be secured to the duration of the study up to 5 years after completion and publishing of the doctoral study.

6.10 Data results and Analysis phase 4.

Section 1 - Demographic

Section 1 was asking regarding demographics Information. Details background such gender, years of experience, and position in the company. The result as below,

Table 34: Details background such gender, years of experience, and position in the company

Respondents	Gender	Age	Department	Working Experience	Working Area	Position	Qualification
R1	Male	36	Fuel Workshop	10-20 Years	Airport Maintenance front line	Executive Engineer	LAE
R2	Male	35	Line Maintenance	10-20 Years	Aircraft Maintenance	LAE	Malaysia DCAM B1.1 UAE GCAA AMEL B1.1
R3	Male	43	Line Maintenance	10-20 Years	Aircraft Maintenance	Aircraft Maintenance Foeman	LAE
R4	Male	36	Line maintenance	10-20 years	Aircraft Maintenance	LAE	LAE
R5	Male	37	Airlines management	10-20 years	Airport Airside	Aircraft Maintenance	LAE & Chartered member Logistic Transport
R6	Male	29	Aero Gas Turbine Engine	Less than 5 years	GE O&G Management Team (Aero Gas turbine engine)	Project coordinator	Degree/ Engine Type course
R7	Male	60	Mechanical	10 Years Academic 30 Years Airlines	Turbine Engine design, Construction, operation and System	Gas Turbine Engine Lecturer	LAE
R8	Male	56	Mechanical	5 Years Academic 17 Years Airlines	Turbine Engine design, Construction, operation and	Gas Turbine Engine Lecturer	LAE/ Master

System							
R9	Male	50	Mechanical	6 Years Academic 25 Years Airlines	Turbine Engine design, Construction, operation and System	Gas Turbine Engine Lecturer	LAE/Master
R10	Male	39	Mechanical	4 Years Academic 7 Years Airlines	Turbine Engine design, Construction, operation and System	Gas Turbine Engine Lecturer	LAE/Master

Section 2 of Background of research

In section 2 of Background of research details case, studies of the Air New Zealand Airlines, Continental Airlines, and Japan Airlines were described. From the content analysis in Phase 1, details interview questions will focus on The Effects of Biojet Fuel on Aircraft Engine: Perspective from Maintenance Personnel. From this correlation, it can be demonstrated by using the result analysis in Phase 2.

i. Storage stability – (water and biological growth)

Questions;

1. In your opinion, will a smaller amount of water in Biojet fuel reduce the maintenance visit? Why?
2. In response to your answer, how will it affect the maintenance cost?

Result and Analysis

Water content whether the small or large amount of biofuel or jet fuel can cause same problems as such water accumulation and microbial growth in fuel tanks. It is not possible to keep aircraft tanks free of water; IATA recommends microbiological monitoring to ensure system remain free of contamination. As such, the routine of fuel tank sump draining goes a long way to prevent accumulation of water and microbial growth.

Nine out ten respondent agreed a reduction in water could reduce the possibility of corrosion at the bottom of fuel tank surface & fuel filter clogging due to microbial contamination in the fuel system. In addition, water particle freezing in the fuel supplied to

the engine can be minimised. Based on this response; the maintenance cost will be reduced when less corrosion and less filter clog occurs.

As to conclude for the question 1, Maintenance cost will be reduced once the less contribution of the water in the storage (Aircraft wing) can be achieved. However, on the other hands, consideration towards the effect will not show much reduction in maintenance cost due to all the contaminants; water is considered to affect airline operations the most regardless on the amount. Every point in the fuel handling will be mandatory to check for the quality of the fuel including the present of water contamination. The most critical juncture in handling the fuel supply chain when it finally enters the aircraft wing and Aircraft fuel system specifically. Safety measures with reliable and cost effectiveness including the water detection system in the refuelling vehicles will be crucial (Chandrasekhar, 2014)

ii. The composition of the biojet fuel compares to Jet A fuel

Questions;

1. In your opinion, will the zero amounts of aromatics in Biojet fuel affect the safety of the engine component? Why?
2. In response to your answer, how will it affect the maintenance cost?

Results and Analysis

With no aromatics content, existing rubber base material, i.e., seals, hoses in fuel system will tend to shrink. This might cause a leak in the fuel tank or fuel lines in return will affect the aircraft safety. However, the major limiting factor of blending the biojet fuel and normal Jet fuel is because of the aromatics. This aromatic is a two-faced on, where with aromatics being currently necessary to preserve the tightness of fuel systems but on the other hand being undesirable from a fuel burn and emissions point of view (Zschocke & Scheuermann, 2012).

Some aromatics contents in literature are to be a major influencing in smoke point. In relationship to the safety functioning of a aromatics in biojet fuel, another technical aspect is their emissions behaviour. According to Zschocke & Scheuermann (2012), consideration of emissions is primarily dependent on the engine fuel burned even at a 30% blend ratio, the aromatics content of the conventional kerosene needs to be below 14.3% for the blend to be within specification requirements.

Therefore, as aromatics context, an interest in getting details information in whether biojet fuel will lead to an improvement in engine components life of a given engine and minimise the carbon footprint on the environment. As cost effective is a concern, reducing maintenance cost in return will be a great opportunity to see when the engines are expected to experience less engine wear in the long run when using biofuel as short-term engine wear when using biofuel has been measured to be less than that of jet fuel.

iii. Fuel thermal stability in the Jet fuel compares to biojet fuel.

Questions;

1. Higher fuel thermal stability contributes to higher combustion efficiencies. In your opinion, does it reflects the maintenance and safety? Why?
2. In response to your answer, how will it affect the maintenance cost? Why?

Results and Analysis

These questions are resulting in misunderstanding among the respondents. Therefore, details explanation on what is thermal stability is defined as below;

Thermal stability is the stability of a molecule at high temperatures; i.e. a molecule with more stability has more resistance to decomposition at high temperatures, as defined by Schmidt (1928).

As the results, 8 of 10 respondents answered, the higher the thermal stability will lead to better combustion efficiencies, the less fuel is required for combustion. It will also give fewer carbon deposits left after combustion; therefore, it will provide a cleaner interior parts of the engine. On contradictory, two respondents have no opinion regards to it.

The stable the molecule composition in the biojet fuel, the highest the thermal stability can be a setback. This in return will create lower maintenance cost, due to less maintenance required in the internal part of the engine and less fuel will be used for engine test for an example during engine ground run.

As per the result above, if the molecule of the biojet fuel is lower and not stable, thermal stability gain in biojet fuel will be lower, enhance more fuel at very high temperature is needed. This is more likely to cause unexpected fuel degradation when the engines operate under such severe thermal conditions. The problem of instability of biofuel may lead to poor engine performance, low efficiency, engine failure, and engine malfunction. As a result, the engine will become less reliable and more vulnerable, maintenance costs will increase, and the lifetime of the engines can be shorted.

iv. The fluidity of the Jet A/A-1 fuel compares to biojet fuel.

Questions;

1. In your opinion, will higher freezing point affect engine safety? Why?
2. In response to your answer, will it prolong the maintenance visit? Why?
3. In response to your answer, how will it affect the maintenance cost? Why?

Results and Analysis

All respondents agreed that when aircraft operates at high altitude, it will be subjected to a very low ambient temperature that can cause freezing of the fuel. With the high freezing point, it will enhance the ability to move the fuel to the engine and will prevent the blockage at some engine components at very low temperature. As its being defined, the freezing point of the aviation fuel is when the temperature at which the last crystal disappears.

At a given very low temperatures at high altitude, its fluidity is measured by the freezing point lower than -40°C had shown the thermal stability characteristics not only provides energy but is also increase safe engine operation in term of heat transfer medium to cool engine components during flight. This will lead to better components operations. As being discussed in Chapter 4, the turbine engine needs to be associated with a heat exchanger or we referring it to Fuel Cool Oil Cooler (FCOC). As it will be associated with Lubrication oil, the operation will be as efficient as a normal jet fuel.

Therefore, it needs to be a good heat sink and not degrade with temperature. It may show high levels of unsaturation and will be prone to oxidative degradation during storage, low hygroscopic nature which it must not easily absorb moisture from the atmosphere & resistance to microbial attack. Thus, it may lead to lower maintenance visit cost in tank microbial growth inspection. Fuel that easy to freeze will cause damage to the fuel lines, fuel driven actuators and might clogged the fuel system. With the high freezing point, the less maintenance visit due to discussion before. This in return will reflect the maintenance cost.

v. The combustion properties comparison from Jet A to biojet fuel.

Questions

1. In your opinion, will zero smoke point increase the engine safety? Why?
2. In response to your answer, will it prolong the maintenance visit? Why?
3. In response to your answer, how will it affect the maintenance cost? Why?
4. In response to your answer, how will it affect the environment?

Results and Analysis

The smoke point primarily depends on the presence of aromatic compounds in the fuels. Therefore, blends with aromatic free synthetic fuels show an improved smoke point. (Zschocke & Scheuermann, 2012) In this question, all respondent agreed that the zero smoke point contributes to the efficient engine. In the question 1 for figure 5, the engine safety might not be affected; however, all respondent agreed that it will affect more on the environment.

Smoke will leave stains at the area behind the engine. More cleaning will be required. If the reduction of a smoke point can go to zero value, less maintenance visit needs to be carried out. However, a wide range of environmental regulations applies to aircraft and equipment. Aircraft engines have certification requirements for CO, HC, NO_x, and smoke emissions. The composition of jet fuel & biofuel is all regulated to limit harmful emissions, ensure proper performance of engines and fuel systems, and avoid engine durability concerns. Reduction of naphthalene in fuel reduces the formation of carbonaceous particles that are potentially harmful because they can cause erosion on turbine blades and form hot spots that can lead to premature engine failure.

As a result, the reduction in maintenance cost will be achieved. However, schedule engine inspection still needs to be obeyed in meeting regulatory flight safety requirement. Indeed, projections on the use of biofuel in the aviation industry, vary significantly, Uncertainties on the possible environmental effects by biojet fuel substitution are reported, concerning the no-carbon greenhouse effect of the air traffic and the greenhouse gas emissions of land use change caused by biojet fuel feedstock provision. Therefore, it is often seen as a promising solution to contribute to reducing the increase of global aviation CO, CO₂, HC, NO_x emissions. However, accurate analysis is necessary.

vi. The contaminants for Jet A/ A-1fuel compares to biojet fuel.

Questions

1. In your opinion, will zero contaminants increase the engine safety? Why?
2. In response to your answer, will it prolong the maintenance visit? Why?

3. In response to your answer, how will it affect the maintenance cost? Why?
4. In response to your answer, how will it affect the environment?

Result and Analysis

Questions above will discuss on contaminants occurs in biojet fuel. All respondents agreed that the zero contaminations in the report shown could give a real impact on the aircraft engine. In advance, the contaminants may lead to microbial growth in aircraft fuel and create blockage filters of fuel system components and scavenge systems. This will result in corrosion and will reduce the components life cycle.

With zero contaminants, less maintenance visit will enhance maintenance cost and manage the risk and mitigate the lost profits.

Section 3 consists of questions on general understanding on biojet fuel.

From the data shown in section 2, it demonstrates that the use of bio jet fuel does affect engine maintenance.

1. *With regards to the use of aviation fuel, do you think Airlines should have a restriction on using biojet fuel in the future? Why?*

From the response, 100% of participants agreed that there will be no restriction on using the biojet fuel in the future. The biojet fuel gave a better advantage to the airlines in term of performance and cost effectiveness. The airline should consider biojet fuel as an alternative to the conventional Jet fuel. In the long run, it will benefit the operators in safe operation, reliable, cost-effective as much towards a reduction in maintenance cost.

2. *Do you think the biojet fuel can reduce the airline fuel cost? Why?*

90 % respondent agreed that when maintenance requirement is less, its impact the whole Airlines operating cost. When less maintenance required on the fuel system while

new fuel results in better performance than the current Jet Fuel it will giving an impact on Cost. 10 % respondent do not agree as respondent mentioned that fuel cost will depend on airlines business model, demand thus in creating revenue. The price for new fuel still can be questionable, where at this stake, the demand is low, and prediction on new fuel can be wrong.

3. Safety is vital in aviation. Do you think the airline should consider using the biojet fuel knowing that it will affect minor components of the aircraft engine? Why?

Safety is vital. In any circumstances, safety cannot be tolerated with anything. Based on the respondent answers, 100 % agreed that the Airlines should consider the usage of biofuel. The challenges remain to biojet fuel producer and researcher, not to be excluded the authority when high-quality standards requirements need to be made. The minor effects of the components will not be the limiting factor of the biojet fuel usage, however, the technical requirements to allowed its to operate in all weather and operational condition, this biojet fuel has not compromised the safety and meet the stringent performance targets.

4. Do you think the airline industry will use biojet fuel shortly? Why?

Based on the respondent answer, 100% agreed that the Airlines industries would use biojet fuel in near future. 50% response that due to safety and cost effectiveness in the maintenance point of view, the Airlines should implement it. 30% respondents agreed that the environmental effects would be a good breakthrough for the biojet fuel usage even though the maintenance department are not directly linked to the environmental responsiveness. While 20% response the awareness of bigger Airlines using it, and the rest of the world need to start using it too.

At present, lack of strong biojet fuel policy retards the deployment of advanced biojet fuel usage and implementation. The lack of long-term takeoff agreement between the biojet fuel producers and the aviation industries is also creating the hesitant, where and lack of financing drives the potential and the greatest impacts on promoting of biojet fuels usage.

However as its progress, those aviation industries are moving towards advanced future biofuel.

5. *What are your major concerns with biojet fuel?*

From the respondent answer, [figure 65](#) below shows the percentage of a reply as accordingly to supply and demand storage capability and supply chain.

Figure 65: Respondents major concerns with biojet fuel

Supply and demand are a major concern where, if biojet fuel is chosen as a priority to be used in the aviation industry, the demand will be increasing rapidly, and the supply will be a top priority to ensure the Airlines can operate like usual. It is considered to be directly linked to the supply chain as more demand, the production from wake to well need to be ensured in a linear relationship.

As biojet fuel is a concern, oxidisation will occur when low temperature is measured in the storage for an extended period. The Aviation is providing the additives to prevent it from causing to gel by improving the cold weather tolerance in biojet fuel but limitation still a factor. A proper solution for storage capability need to be proposed and need to ensure the reliability cannot be doubtful.

6. *Do you think biojet fuel can be profitable for the aviation industry? Why?*

100% response the biojet fuel will be profitable for the aviation industry. In the long run cost reduction in maintenance & operation will benefit the aviation industry. Aviation

fuel price accounts for such a significant share of aviation costs that managing price increases, and price volatility is an ongoing challenge. Whether biofuels could help mitigate either of these concerns is a now. Fuel efficiency in aviation has improved significantly. Continued improvement in fuel efficiency will be critical to meeting the long-term goals of the aviation industry to curtail emissions issue. The industry sees biojet as a valuable complement to continued efficiency improvement in its strategy to achieve these long-term goals.

6.11 Discussion and conclusion for Chapter 6

In phase 3, the semi-structured interview creating a broader view in understanding the Aviation Company in biojet fuel view. The perception and critical review will give feedback on what context biojet fuel need to adapt. The main linear response can be pulled out and be carry forward to create a phase 4 interview. The same Aviation background but different department resulting in varies response hence giving the best result in tackled a different angle view.

Phase 4 will lead to validation of the hypothesis created in the beginning with the support of the result in phase 3. A Smaller amount of respondent but focusing on License Aircraft Engineer background will create a deeper relationship of Aircraft Maintenance and the usage of biojet fuel. Besides the structured interview will lead to direct subject focus goal.

Combining the Phase 3 and Phase 4 in this chapter answering the hypothesis mentioned in chapter 1 previously. Details economic analysis on energy policy incentive mechanism to promote biofuel will be discussed in the next chapter.

INTENTIONALLY LEFT BLANK

CHAPTER 7

ANALYSING THE IMPACT FACTORS OF BIOFUEL TO THE COMMERCIAL AIRCRAFT OPERATION AND ECONOMIC ANALYSIS TOWARDS ITS SUSTAINABILITY.

7.0 Introduction

A new alternative energy in the aviation industry has been accepted since the beginning of the new millennium with the approval of a new fuel from the biomass, which was introduced in 2008. The first biofuel flight was tested by the Virgin Atlantic that used coconut and Babassu on their Boeing 747 (IATA Alternative fuels, 2009). It has been a remarkable achievement as more biofuel flights have been tested and even scheduled up to the World Cup flight in Brazil in 2014, whereby 200 commercial flights participated with more than 92,000 litres of Honeywell Green Jet Fuel (Joanna, 2014).

The new energy has promised better fuel efficiencies, environmentally friendly, and vital to the airlines as it saves cost. The alliances for the changes have been associated with sustainability, mainly focusing on environmental, social, and economics (Environment, 2006). Better environmental care by reducing Co₂ distribution has been proven, as most reports from the biofuel flight tests produced positive results (IATA, 2009a). The direct impact contributed by the Aviation magnifies the effects of pollution by directly affecting the ozone depletion in the upper reaches of the atmosphere. The social elements, in this case, can be related to the Airlines, the Maintenance Repair and Overhaul (MRO), the government (authorities), and the biofuel producers (related to).

Besides, governments, especially from the Europe, USA, and Australia, have contributed by giving full support, specifically in subsidies and funding for many and more on-going biojet fuel projects. Hence, a new economic measure in finding a realistic opportunity of an incoming new energy is shared based on a common goal towards sustainability. The hurdle in approving the new energy to be used has passed. In the long run, more dedicated maintenance view needs to be focused, especially in a broader perspective.

Technology development in aircraft that has contributed towards fuel efficiencies can be varying. This includes lighter material in new airframe and cabin interior, new engine development, and new alternative energy – the biojet fuel (Boeing, 2008). This technology offers both opportunities and risks. The rapid changes in aircraft development bring potential in Airlines in maintaining the benefits in economic and environmental, but it also needs to look into the adaptation of MRO. Due to its reliability and maintainability, it is crucial to ensure if the new fuel is not harmful to the engine fuel system and its subsystems. In this chapter, the discussion of the relationship which has been discussed in chapter 5 and 6, into how this new alternative energy creates the sustainability mentioned and the factors that affect the impact on biojet fuel used in commercial aviation as in [figure 66](#); its urgencies, risks, and opportunities. (Noh et al., 2015)

It is focused on the successful adaptation of biojet fuel to MRO that can become another successful chapter in aviation.

Figure 66: The impact factors of biojet fuel on commercial Aircraft

The urgency and the need of new energy have been focused when climate change issues were highlighted in IPPCC 1996, and the fact that fossil fuel covers over 12% of the Airlines operational cost (IATA MCTF, 2013).

The first urgency in Climate change and global warming due to CO₂ emissions is well

characterised and is independent of source location due to its relatively long atmospheric lifetime. Aircraft engines produce emissions that are similar to other emissions generated by fossil fuel combustion. However, most of these emissions are released directly into the upper troposphere and lower stratospheres, whereby they are believed to have a different impact on atmospheric composition. (ICAO, 2010)

The second urgency is the issue of fuel as fuel price has fluctuated greatly and this has given an enormous impact on the Airlines around the globe. The world market forecasts that the cost and consumption of jet fuel will tremendously increase annually (IEA, 2006). Although new improvements on Aircraft engineering and technology have been developed and are indeed growing rapidly, a unique opportunity that can offer global development, and at the same time in reducing the zero carbon, is to utilise the new alternative energy in the aircraft power plant system.

7.1 The Risks and the Need for a New Approach

In developing sustainable development, some challenges need to be addressed. Two Issues of Alternative energy in the usage of biojet fuel in the aviation industry can be categorised as technical risks (Which already discussed in the previous section) and quality risk. The technical risks are Thermal stability in the relation to fuel system components coking, Storage stability for biological growth, combustion properties, the performance of the system at low temperature, and the effect of low-density fuel towards aircraft range. Besides, flying at a very high altitude, and starting in freezing or hot weather are the top priorities, excluding engine relight.

7.2 The risk outcomes

The outcomes of the investigation being carried out in Phase 1 until Phase 4 studies based on different analysis techniques can be captured in SWOT analysis. S.W.O.T stands for *Strengths*, *Weaknesses*, *Opportunities*, and *Threats*, and this analysis generates results to be used for the marketing plan in presented for biojet fuel, thus clearly identifying, and understanding the decision making for the business plan.(Phyllis Pollack, 2013) Thus, the expected outcome is a useful framework for reviewing the strategy, position, and direction

of the new business trend in the global biojet fuel market and industries.

Table 35: The table portrays an example of a SWOT analysis that can be identified for biomass use to produce renewable energy

Strengths	Opportunities
<ul style="list-style-type: none"> • The carbon is offsetting available due to the reduction in carbon footprint. • Long term cost-benefit advantages. • The ability to meet demand and supply requirements. • The reduced dependence on geographic, political, and climatic factors. • The advantages regarding land usage and development (Algae). • Customer satisfaction regarding using clean fuels and customer appreciation. • The long-term economic benefits the airlines in shifting from a fluctuating and non-reliable fuel source to a reliable, cheaper, and cleaner fuel. • Biojet fuels are little or no toxic • The carbon cycle is relatively short • A “greener” jet fuel will be welcome by customers, government and general public 	<ul style="list-style-type: none"> • The dependency on crude oil will decrease • A large percentage of Jet A-1 fuel can be replaced • Using blends of biojet fuels with Jet A-1 provides short-term opportunities • New business • New alliances • New job to biojet fuel production • Extra distribution link for agricultural products, increases income farmers, less subsidy needed • Biofuel prices are constantly decreasing through process development • Contribute to IATA’s goal of reducing airline emissions • Incentive promotes the usage of biofuel will be beneficial to both party Producer- end user
Weaknesses	Threats
<ul style="list-style-type: none"> • Change control from existing fuels to the new biojet fuel regarding acceptance and integration and quality assurance. <p>The production depends on external factors such as weather conditions and pest attacks</p> <ul style="list-style-type: none"> • Lack of market understanding for “drop-in” biojet • Nonavailability of adequate models for large scale implementation. • Increase in prices of aviation fuel and a projected decrease in supplies over the next four decades. 	<ul style="list-style-type: none"> • The biojet fuel market is relatively new • The legal requirements in acquiring land resources in areas identified most suitable for algae production. • Policy between OEM and Aircraft Operators need to running in parallel. • The price of new fuel • The ability to meet demand and supply requirements (Still can be questionable) • Production is limited due to land availability for feedstock production

7.3 The opportunity- New economy and alliances

It has been acknowledged that the oil prices have a big significant impact on the airline industry, and the emergence of biojet fuel offers the opportunity to the air transport industry to create a new economy. According to Glover (2013) –MASBI 2013, developing sustainable new energy sources for aviation provides economic opportunities and builds on the region’s legacy of leadership. In fact, in the direction to develop sustainable

environment, the influence of social, economic, and operation will have its direct linear relationship.

However, going for green and being environmental friendly will put the extra cost to economics. Therefore, creating new energy in new biofuel business, in a different perspective, creates more job opportunities and provides new economy in the industry, which is vital to achieving it is a key objective and its main aim called “Sustainability.”

As discussed earlier, sustainability in this study refers to everything that we need for our survival and wellbeing, which depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony that permits fulfilling the social, economic, and other requirements of present and future generations. It is vital to ensure that we have and will continue to have water, materials, and resources to protect human health and our environment.

As mentioned earlier in section [2.2 in Figure 9](#), the economy is one of the four pillars of sustainability for air transport development concentric circle adaptation in Aircraft MRO. Of the four pillars, economic viability is vital to the aviation industry as its long-term strategy to diversify fuel supply (MASBI, 2013). It has been recognised that it has the potential to contribute to price stability and cost reduction while reducing aviation environmental footprint.

Additionally, the new design and engineering for the global economy services will include mostly the rural area, whereby more opportunities are provided to the locals. The size and scope for supplying enough for the biojet fuel demand will be adjusted in the areas that are most suitable for the biomass plants to be planted. This will create externalities of industrial, economic, and social processes as the market needs to follow the world works and sustainability, and the whole process needs to be understood as one form of a cultural idea.

In the changes towards sustainability, environmentalists alone will not work. The requirement all alliances with different roles, including businesses, governments, environmental authorities, and other biojet fuel developmental organisations. In other words, the relationship between these parties (the businesses entity, government,

environmental authority, and biojet fuel –developmental organisations) is critical to delivering a seamless, high-quality experience to support this change process. Their full support and critical monetary subsidiary support will be essential to the change process as well.

Hence, to achieve sustainability in the aviation industry, all these parties are interdependent. Therefore, there will be many things that can be gained from effective alliances between airlines and the other parties. Besides, long term policy from the policy makers would help the aviation biofuels to be developed into an established industry. If aviation stakeholders and policy makers play their roles in the same direction, the aviation biofuel industry will be capable of meeting growing demands, and in turn, it can provide economic benefits to the regions, countries, and the aviation industry. This shows that sustainable biofuels will become economically viable in the aviation industry and compete with petroleum-based fuels as costs are lowered through the improvements in production technology and economies of scale in production.

As a conclusion, building on the strengths and alliances with continued efforts from all parties can chart the course for economic sustainability in the aviation industry. Moreover, as discussed at the beginning of the research, it has been recognised that petroleum based products are subjected to significant fluctuations in cost, which have a tremendous impact, regarding the cost and the airline company.

In fact, the motivating factors that have led the aviation industry towards alternative jet fuels are related to cost-benefit. As mentioned earlier, this section discusses in detail the reasons for the development of alternative fuels to be utilised by the aviation industry from the perspective of maintenance cost benefits.

The use of biojet fuel, which originates from non-petroleum sources, in the airline industry is once again growing due to the advantage of its cost factor. It has been acknowledged that alternative fuels, if available in sufficient quantities, offer the potential to reduce the cost in the airline industry. According to Demirbas (2008), there are many advantages as far as the

use of biojet fuel is concerned. From the economic perspective, as illustrated in Figure 8, it leads to business sustainability.

The following illustration demonstrates that the use of biojet fuel has the potential to help the aviation industry sustain their business by focusing on the following model: fuel diversity leads to a reduction in the dependency on imported petroleum, which can promote international competition, with the ultimate goal of attaining business sustainability. This economic advantage is related to cost benefits. If the fuels used by the airlines industry can be diversified, this will assist in reducing the dependency on imported petroleum. In other words, alternative fuels are financially competitive when petroleum costs are high. Since the energy crisis of the airline industry in the 1970s, 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.

Figure 67: Advantages of biofuel from economic perspectives

The results of the study showed that there was an increase in the frequency of the flight (flying), which reflects the cost benefits. The study concluded that the use of biojet fuel could provide cost benefits regarding three aspects: asset (aircraft), profit, and its usage.

7.4 Proactive and predictive monitoring systems

Hence, in determining the cost-benefit analysis, first, the details need to be understood for measurement purposes. The costs and benefits need to be identified from the implementation of using the new alternative energy towards the direct and indirect effects on the Airlines and the maintenance department. More reasonable approximations of fuel systems maintenance can be achieved when more airlines use biojet fuel and data sharing among the maintenance-based framework is employed.

Measurement of costs and benefits can be obtained through the observations of the behaviour of biojet fuel producers, suppliers, and consumers, whereby, in this case, is the Airlines. Also, the biojet fuel market data compilation should measure the demand and the supply, through observations of the usage of biojet fuel and the usage trending.

Within a period, the saving fuel analysis can be measured, and the aggregation of benefit and cost can be associated. All cost benefits and analysis can be seen from the step by step adoption, as drawn by Gines De Rus, in [figure 68](#) below.

Figure 68: Steps of implementing Cost benefit analysis

In contrary, when it comes to maintenance, unscheduled maintenance events are the most significant cost driver for airlines. This result is unwanted in operational inefficiencies. With the implementation of new biojet fuel, the real-time awareness of an aircraft's status that reduces disruption and maintenance costs must be looked into. Current researchers that utilise the connections of biojet fuel projects can predict the trending and alert future unplanned maintenance events. When new opportunities for efficiency are created through data accumulation, they need to be examined so that the airlines can transform their maintenance practices utilising these tools and the elements that benefit these enablers can be employed in day-to-day operations.

7.5 The regulatory- Energy Policy in Incentives policies being applied in the world

It is widely accepted that the introduction of biofuels cannot be done using current market mechanisms because their high production and distribution cost, at least during the initial stage, limit their competitiveness with fossil fuels. It is not unreasonable to assume that until concerns surrounding cost, sustainability and policy support are addressed, aviation

biofuels will not form a significant share of the aviation fuel market (Gegg et al., 2014). Then, all States interested in promoting the use of biofuels are going to use special incentives to gain public acceptance of these new products.

There are several feasible options for incentive policies, varying on the type of economic mechanism applied, subsidies or quotas, and in the phase of the production-consumption cycle where is applied to, farming, recollection, manufacturing, distribution or consumption. Each State or even part of it, like the Federal States of USA and Canada, may select the combination of measures that fits the best to its particular environment and produces less interference with other related activities, like food agriculture, rural development or other energy production.

The key instruments widely adopted to foster production and increase consumption have been mandatory blending targets, tax exemptions, and subsidies. Also, governments have intervened on the production chain by supporting intermediate inputs (feedstock crops), subsidising value-adding factors (labour, capital, and land) or granting incentives that target end-products. Import tariffs have also played a significant role in protecting national industries from external competition (Sorda et al., 2010).

In the United States (Yacobucci, 2012) there were some legislative actions to launch alternative energy production, like the 2005 Energy Policy Act, the 2007 Energy Independence and Security Act and the 2008 Farm Bill. Biofuels, in this case, transportation fuels, produced from plants and other organic materials, are of particular interest. Ethanol and biodiesel, the two most widely used biofuels, received significant federal support in the form of tax incentives, loan and grant programs and regulatory programs. The [Table 36](#) listed 22 recent Federal programs that provide direct or indirect incentives for biofuels, grouped by administering agency. Some of them are long term; some have a fixed deadline, and others need Senate or Congress approval for continuity.

Table 36: US Federal programs are providing direct or indirect incentives for biofuels (Congressional Research Service).

Administering Agency	Program	Description
Environmental Protection Agency (EPA)	Renewable fuel standard	Mandated use of renewable fuel in gasoline: 4 billion gallons (2006), 36 billion gallons (2022)
	Volumetric Ethanol excises tax credit	Gasoline suppliers who blend ethanol with gasoline are eligible for a tax credit of 0.45 USD per gallon of ethanol
	Small ethanol producer credit	An ethanol producer with less than 60 million gallons per year in production capacity may claim a credit of 0.10 USD per gallon on the first 15 million gallons produced in a year
	Biodiesel tax credit	Producers of biodiesel or diesel/biodiesel blends may claim a tax credit of 1 USD per gallon of biodiesel
	Small agri-biodiesel producer credit	An agri-Biodiesel (produced from virgin agricultural products) producer with less than 60 million gallons per year in production capacity may claim a credit of 0.10 USD per gallon on the first 15 million gallons produced in a year
	Renewable diesel tax credit	Producers of renewable diesel may claim a tax credit of 1 USD per gallon of renewable diesel
	Credit for production of cellulosic biofuel	Producers of cellulosic biofuel may claim a tax credit of 1.01 USD per gallon, under some specific conditions
	Special depreciation allowance for cellulosic biofuel plant property	Plants producing cellulosic biofuels may take a 50% depreciation allowance in the first year of operation, subject to certain restrictions
	Alternative fueling station credit	A credit up to 30,000 USD is available for the installation of alternative fuel infrastructure, including E85 (85% ethanol and 15% gasoline) pumps
Department of Agriculture (DOA)	Biorefinery Assistance	Loan guarantees and grants for the construction and retrofitting of biorefineries to produce advanced biofuels
	Repowering Assistance	Grants to biorefineries that use renewable biomass to reduce or eliminate fossil fuel use
	Bioenergy program for advanced biofuels	Provides payments to producers to support and expand production of advanced biofuels

	Feedstock flexibility program for producers of biofuels	Authorizes the use of CCC (Commodity Credit Corporation) funds to purchase surplus sugar, to be resold as a biomass feedstock to produce bioenergy
	Biomass crop assistance program (BCAP)	Provides financial assistance for biomass crop establishment costs and annual payments for biomass production; also provides payments to assist with costs for biomass collection, harvest, storage, and transportation
	Rural Energy for America program (REAP)	Loan guarantees and grants for a wide range of rural energy projects, including biofuels
	Biomass Research and Development	Grants for biomass research, development and demonstration programs
Department of Energy (DOE)	Biorefinery project grants	Funds cooperative R&D on biomass for fuels, power, chemicals and other products
	Loan guarantees for ethanol and commercial byproducts from various feedstocks	Several programs of loan guarantees to construct facilities that produce ethanol and other commercial products from cellulosic material, municipal solid waste, and/or sugarcane
	DOE Loan Guarantees program	Loan guarantees for energy projects that reduce air pollutant and greenhouse gas emissions, including biofuels projects
	Cellulosic ethanol reserves auction	Authorizes DOE to provide per-gallon payments to cellulosic biofuels producers
U.S. Customs and Border Protection	Import Duty for fuel ethanol	All imported ethanol is subject to a 2.5% ad valorem tariff; it is also subject to a most-favoured-nation added duty of 0.54 USD per gallon
Department of Transportation (DOT)	Flexible fuel vehicle production incentive	Automakers subject to Corporate Average Fuel Economy (CAFE) standards may accrue credits under that program for the production and sale of alternative fuel vehicles, including ethanol/gasoline flexible fuel vehicles (FFVs)

As it can be seen, six different agencies and departments without any apparent coordination are administering the support schemes. Three major Federal legislative actions previously mentioned, the 2005 and 2007 energy laws and a farm bill have originated many of them in

2008. A significant number of them are temporary rules terminating at the end of 2011 or 2012 and will need Congress approval to be extended.

The schemes can be broadly divided into six types:

- i. A mandate for the use of fixed amounts of renewable fuel in gasoline
- ii. Tax credits for gasoline suppliers and biofuel producers,
- iii. Financial help for the opening and expansion of supply and production facilities, either new or refurbished
- iv. Financial support for Research and Development
- v. Reduction of import duties for some kinds of biofuels
- vi. Incentives to manufacturers for production and sale of alternative fuel vehicles but can be resumed in two groups: a mandate for blending and tax measures.

The distribution of incentives goes along the whole biofuel chain, from the agriculture to the vehicle, passing through the production plants, the refineries, and the distribution, with selective inclusion of some products (fuel ethanol) in an import duty rebate. All these policies have a cost for the taxpayer, diminishing the public treasure revenues. No information has been published on that amount.

The second generation biofuels for transport are included in the Renewable Fuel Standard (RFS) law. President Obama supports the preservation of the RFS, as a part of an “all of the above energy strategy”, based on a public-private finance scheme. However, there is fear that affordable private capital will not be available to support any major capacity building for advanced biofuels, putting the RFS itself, with its steep annual volumetric increases, in considerable jeopardy. The resulting lack of capabilities and rewriting of mandates to support lower levels of capacity building may result in market uncertainty and further reduce investor interest in the sector.

A large variety of biofuel support policies are in place in the EU Member States (Wiesenthal et al., 2009), ranging from command and control instruments such as standards and quotas, over economic and fiscal measures, such as tax exemptions, to information diffusion, and addressing different stages of the biofuel chain.

As first generation biofuels are a mature product, the policy focus today lies on facilitating their market entry rather than R&D support. As the production cost of biofuels is well above those of fossil fuels, incentive policies are needed to create the biofuels market. This is done, as in the United States, of two types of instruments: subsidisation or prescription of a mandatory production. In the first case, a tax reduction scheme brings the price of biofuel down at the cost of the equivalent fossil fuel, reducing the State income.

In the second case, fuel providers are obliged to blend a certain percentage or gross amount of biofuel in their product. In this way, fuel providers and the transport users carry the additional cost, and a certain reduction of demand is caused. Similar schemes may be applied to other elements, like fiscal support to the sale or utilisation of dedicated vehicles, either in their sale price or the owner taxes or the circulation conditions e.g. allowing bio-fuelled vehicles to circulate by restricted lanes or to have access to large cities downtown.

Unlike the United States, the EU has tried to get a higher level of coordination in the State aid policies, defining global targets and standardizing legal and economic procedures. Nevertheless leaving the Member States some open space to determine the level of each policy application and the mix of support schemes more adequate to their particular characteristics. In any case, the used tools are very similar to those used in other countries, divided into fiscal measures and blending obligations.

The legal framework for the fiscal measures is the *EU Energy Taxation Directive 2003/96/EC* that allows exempting all types of biofuels from taxes if:

- The tax exemption or reduction does not exceed the amount of taxation payable on the volume of renewables used;
- Changes in the feedstocks prices are accounted for to avoid overcompensation
- The exemption or reduction is authorised may not be applied for more than six consecutive years, renewable.

In April 2014 the European Commission introduced new guidelines on state aid for renewable energy (EU, 2014), including biofuels (EBTP, 2014), with the purpose of providing a framework for designing more efficient public support measures that reflect market conditions. According to the Commission Vice-President in charge of competition policy,

Joaquín Almunia, Europe should meet its ambitious energy and climate targets at the least possible cost to taxpayers and without undue distortions of competition in the Single Market.

Three months before, on January 23, 2014, the Commission had published a communication titled: *A policy framework for climate and energy in the period from 2020 to 2030*. About biofuels, the communication, confirmed the relevance of the 2020 targets (10% of renewable fuels for the transport sector) and acknowledged the achieved progress, with a 4.7% rate in 2010 compared with a 1.2% in 2005. Based on the experience, the Communication concluded that first generation biofuels have a limited role in decarbonising the transport sector and a range of alternative renewable fuels, and a mix of targeted policy measures building on the Transport White Paper are thus needed to address the challenges of the transport sector in a 2030 perspective and beyond. No specific 2030 target was announced.

The April 2014 guidelines on State aid made reference to biofuels for trying to reduce progressively support of first generation biofuels (called food-based biofuels), without causing a sudden disruption in the industry. It considered that investment aid in new and existing capacity for food-based biofuels is not justified, given the existing overcapacity in this market, but this aid can be justified for increasing capacity in advanced biofuels or the conversion of the existing facilities in these. Thus, investment aid to support food-based biofuels is stopped with the entry into force of these guidelines.

Operating aid for first-generation biofuels will cease at the end of 2020. This aid can only be granted to the production of plants that started operation before 31 December 2013 until the plant is fully depreciated but in any event no later than 2020.

On biofuels subject to supply or blending obligations, aid can be provided if a Member State can demonstrate that the aid is limited to sustainable biofuels that are too expensive to come on the market with a supply or blending obligation only. The concept of “sustainable biofuel” refers to those fulfilling the sustainability criteria set out in Article 17 of the Directive 2009/28/EC (EU, 2009).

During the second half of 2013, both the European Council and the European Parliament were extensively discussing the possibility of putting a cap on the first generation biofuels utilisation and how to include the ILUC factor in the accounting of the environmental impact of biofuels. No agreement was reached, but the issue is expected to appear again after the recent European Elections, with the goal of achieving a final decision at the end of 2015.

On the blending obligations, each country may apply its selected amount, based on a percentage of energy or volume, making it indicative or obligatory or minimum level. For example, Estonia, Greece and Lithuania have only indicative blending amounts, and Denmark adopted a first-ever obligatory quota in 2011. Those blending levels may be different for biodiesel and bioethanol, and have been slowly increasing during the last years. [Table 36](#) shows the status of blending obligations in the EU and Norway (Associated State in bioenergy policies) in the year 2011. Sales of biofuels reached 13.9 million tonnes; a 77% of biodiesel, 21.5% of bioethanol and 1.5% of the vegetable oil. As it was indicated before, the present mandate is 5.75%, and the final target is 10% of renewable content in 2020.

Table 37: Blending obligations in the EU, measured in % of energy (Vecchiet, 2011).
*indicates % by volume

Member State	Total %	Biodiesel %	Bioethanol
Belgium	4	-	-
Bulgaria	5*	4*	2*
Czech Republic	-	6*	4.1*
Denmark	3.5	-	-
Germany	6.25	4.4 (min)	2.8 (min)
Estonia	5.75 (indicative)	-	-
Ireland	4*	-	-
Greece	5.75 (indicative)	-	-
Spain	7	6 (min)	3.9(min)
France	7*	7*	7*
Italy	4	-	-
Cyprus	2.5	-	-
Latvia	5.75*	-	-
Lithuania	5.75 (indicative)	-	-

Luxembourg	-	-	-
Hungary	5.75	4.4*	4.4*
Malta	-	-	-
Netherlands	4.25*	3.5	3.5
Austria	5.75	6.3 (min)	3.4 (min)
Poland	6.2	-	-
Portugal	5	6.75*	-
Romania	5.75	5*	5*
Slovenia	5.5	-	-
Slovak Republic	5.75	5.2*(min)	3.1*(min)
Finland	6	-	-
Sweden	5.75 (indicative)	-	-
United Kingdom	4*	-	-
Norway (non-EU)	5*		

The USA and the European States are not the only countries with mandates (Lane, 2013). The Thirteen American States, including Argentina, Brazil, Canada, Chile, Costa Rica, Ecuador, Jamaica, Mexico, Panama, Paraguay, Peru, Uruguay and the United States itself have different blending obligations, putting more emphasis on ethanol than in biodiesel. Some federal countries, like Canada, use different figures in each one of its States.

In the Asia-Pacific region, other twelve States have implemented this kind of policies, namely Australia, China (in nine provinces only), Fiji, India, Indonesia, Malaysia, New Zealand, The Philippines, South Korea, Taiwan, Thailand and Vietnam. Ten African States, Angola, Ethiopia, Kenya, Malawi, Mozambique, Nigeria, South Africa, Sudan, Zambia, and Zimbabwe have ethanol blending obligations, but South Africa, who has a biodiesel mandate as well. 62 of the world larger economies, with the notable absences of Japan, Russia, and the Arabian Gulf States, are on the list. The highest consumers Brazil, China, EU, and the United States are targeting average mixes of 10-15% in the 2020-2025 period (Lane, 2013).

In the Proceedings of the Workshop on March 20, 2012, in Brussels (Bauen et al., 2012a) there are some examples of financial aid possibilities to build up second generation biofuels production capacity. There is a consensus on the need of public financial aid for Research

and Development and on the convenience of public-private consortia for the initial phases of the production. The banking sector offers a very uneven perspective. Some public banking institutions, like the European Investment Bank (EIB), are lending considerable sums to renewable energy projects. EIB itself lent 4,500 million euros in 2011, although the largest part went to well-established sectors, like wind energy.

The private banking is a bit hesitant to finance biofuels because of their financing experiences with the first generation biofuel projects, the suffering of current overcapacity and dependency on frequently changing policies, sometimes in different countries around the world, but often within the same State, according to the fluctuations of the economy.

The key success factors that any bioenergy project should bring to the table, when requesting for bank financing are:

- *logistic and location*
- *price risk management*
- *feedstock supply with easy and assured access*
- *assured take-off contracts*
- *convincing capacity utilisation expectations (equal or higher than 75%)*
- *bring in experience management*
- *comply with sustainability criteria*

In the case of the aviation biofuels, most of those conditions are very far from being confirmed, what makes direct financing by commercial banks very unlikely without the direct participation of the Governments through any of the tools before commented.

7.6 Discussion

The Energy Policy for this new biofuel and biojet fuel in particular has different characteristics, which need to be adjusted as local market conditions is a concern. To choose one condition or policy to applied for worldwide is too risky. Based on the experienced gain from US and EU, according to (Ziolkowska et al., 2010), it is possible to reach an agreement by reviewing one by one their main features.

Indicative/mandatory targets: Indicative targets give more flexibility for taking into account the particular conditions of different countries and for adapting to the changing results of yearly crops. Mandatory option largely determines the target credibility, meaning more efforts by the governments to achieve the objectives. With this, means that the markets have greater certainty for planning and undertaking investments.

Volumetric/percentage targets: Volumetric mandates reduce uncertainty faced by biofuels producers and farmers. Percentage targets address the commitment of the sector in meeting the overall greenhouse emissions Kyoto Protocol limits. The interaction with the policy or technical restriction towards the impact of using biojet fuel will lead to the effectiveness of either type of mandate or conditional For instance; older road vehicles cannot use higher blends and limit the applicable percentage of biofuel.

Incentives for second-generation biofuels/quantitative distribution of mandate by type: The first approach, used by the EU, is more flexible in that the volume of second generation biofuels is related to their competitiveness on other biofuels. The US approach provides more certainty by setting a mandated volume, but this mandate can be put aside depending on the technology available, and this undermines its theoretical advantages.

Supranational/country level strategies: The current decentralised approach of the EU has the advantage of allowing countries to find the most efficient means to achieve the targets, which may differ country by country. In the USA, it is the Renewable Identification Number (RIN, a 38 character numeric code that goes with each biofuel package, identifying its vintage, volume, and fuel classification) with this the market will allow the production and distribution to move at a very best cost effective throughout the region.

In the subject of changing the trend of energy consumption in the Aviation industry, two broad types of instruments can be used and be adapted by the policy-makers. The traditional regulatory approach is sometimes referred to as command-and-control approach. This sets the specific standards across the air transportation and airlines that produce CO₂, or it can use economic incentive or market-based policies for energy producers and Airlines to adhere to the specifications set.

There are two basic types of traditional regulatory approaches: a) technology or design standard that mandates specific control technologies, or b) production processes that airlines must use to meet emissions standard, (International Energy Agency, 2010). Whereby, in this case, the use of biojet fuel and the implementation of 'bio fees' to the outbound flight in Europe.

Looking at the traditional regulatory and voluntary approaches are valuable policy tools for some types of environmental problems, incentive-based policies are becoming increasingly popular as tools for addressing a broad range of environmental issues, for climate change. Specifically, Market-based approaches or incentives provide continuous inducements and financial to encourage polluting entities to reduce releases of harmful pollutants. As a result, with these market-based approaches generate an incentive for the private sector to incorporate pollution abatement into production or consumption decisions and to innovate in such a way as to continually search for the least costly method of abatement. (Benito, 2008)

With increasing demand and decreasing marginal fuel efficiency improvements, the contribution of aviation to climate change about other sectors is projected to grow in the future, but it is hard to predict how much (Sgouridis et al., 2011). Some analysis opens the incertitude margin for the EU ranging from 10% to 50% of all greenhouse gas emissions by 2050.

According to the IEA (International Energy Agency), biofuels could meet 27% of the transport fuel demand by 2050 (Vessia et al., 2013), with a pivotal role played by advanced biofuels, that need to be rapidly deployed and scaled up. This task would require great and fast progress in three different areas:

- Ensure a stable supply of sustainable feedstocks
- Support demand by establishing a specific mandate for advanced biofuels by 2020 and beyond
- Establish mechanisms to finance first of their kind advanced biorefineries

In favour of this approach success in Europe, there is a stepping up of the incentives for second generation biofuels Research & Development and Innovation with funds provided by

the Seventh Framework Programme (FP7) and Horizon 2020 programs. As the target of reducing greenhouse gas emissions by 80% by 2050 will require a substantial contribution from the transport sector, implying an increase of biofuels to an 8-times larger amount than today.

One of the initiatives financed by FP7 funds is the Initiative Towards Sustainable Kerosene for Aviation (ITAKA, 2016), a collaborative project aimed to produce sustainable renewable aviation fuel end to test its use in existing logistic systems and normal flight operation in Europe. Led by a consortium of aerospace and fuel companies, with academic collaboration, ITAKA intends to make a contribution to the 2 million tonnes of aviation biofuel target by 2020, included in the Flightpath 2020 program but delayed due to great logistics difficulties up to the year 2030.

A very interesting event, related to ITAKA program, is taking place in Norway since February 2016. The Oslo Airport Gardermoen has agreed with Air BP the mixing of 790 tonne of biofuel in the general fuelling tanks of the facilities. The fuel has been provided by the Finnish company NESTE Oil, elaborated from Spanish camelina. Three airlines accepted to pay an undisclosed amount of money to be allowed to count that fuel in their ETS balance. It is evident that some economic incentive is in use, but no official figures on that detail have been published. The owner of the airport AVINOR has a “green fund” which might have been utilised for that purpose (ITAKA, 2016).

Negative conditions are also important, starting from the strong controversy about the long-term use of first generation biofuels, and the slow deployment of the second generation biofuels production plants and a great un-definition of the type of feedstock and processes to be used. The significance of measures on the supply side (Vecchiet, 2011) may, therefore, increase as a tool to steer a growing biofuel market into the desired direction, yet an additional cost compared to a least-cost approach. A crop specific feedstock support subsidy like the energy crop scheme may help to direct the crop mix into an environmental and landscape-beneficial pathway.

It is important to learn from bad experiences, as the ones reported by Kant and Wu (2011) about the collapse of *Jatropha* as a global biofuel in India, China and Brazil and other

developing countries that decided to introduce mandatory blending over increasingly larger parts of the country. However, the results are anything but encouraging, with actual yields far below expectations. It appears to be an extreme case of a well-intentioned top-down climate mitigation approach, undertaken without adequate preparation and ignoring the conflict of interest and adopted in good faith by other countries, gone awry bringing misery to millions of poorest people across the world.

A new and very interesting point are the standardisation of the ILUC evaluation techniques that may allow establishing target regarding climate change effects, like CO₂ equivalent emissions, instead of mandates based on volume, weight or energy. At this moment, there is no agreement on how to calculate ILUC effect with a good level of accuracy, although there are different studies on the subject (Bailis and Baka, 2010). Some ecologist groups are suggesting that certain types of feedstocks produce biofuels with very low life cycle CO₂ savings. This will make undesirable from an environmental point of view although may be considered positive from an economic or supply security approach.

The air transport sector can take a good note of the lessons of other transport modes experience. It has some advantages from the technical point of view because there is an excellent homogeneity in the vehicles and engines and the specification of the used fuel. The selection of a drop-in policy makes very clear the feature of the biofuels to be utilised by this sector. This puts the so-called “blend wall” (the maximum percentage of blended biofuel that is acceptable by the operators) at 50%, a quantity much higher than in road traffic. At the same time, the specific features of aviation kerosene do not allow the use of most of the current first generation biofuels and strongly reduce the candidate feedstock numbers to a few types (jatropha, camelina, urban waste, algae and some others) of second or third generation.

The existence of EU Emissions Trading System that gives biofuels a zero emission factor may be taken as an incentive for biofuel use. However, the present low price of carbon allowance makes it not very significant. At the same time, the present air transport fuel distribution and logistics system make difficult to control, through the existing monitoring, reporting, and verification system, the credits that specific airlines should be given (SAFUG,

2010). The likely change of the present regional ETS to a worldwide system, perhaps based on an offsetting mechanism, can be influential in the re-evaluation of this incentive.

One additional problem may be the competition with other transport modes. If road transport has to achieve 10% of renewable energy by 2020, that may cause a shift of all available sustainable biomass to road transportation biofuels production, in particular if the first generation biofuel production is limited or eliminated. The study from Heraghty et al. (2013) found that the establishment of a Sustainable Aviation Fuel industry (HEFA and FT) in Australia is technically feasible, but identified the importance of supportive policy environment, in particular, a balanced policy environment that incentivises the production of all renewable transport fuels equally.

Policy mechanisms for supporting alternative fuels in aviation should comply with the following principles (Bauen et al., 2012c):

- Parity with other economic sectors
- Maintain the competitiveness of this transportation mode
- Ensure high sustainability standards
- Temporary support mechanisms
- Focus on reducing investment risk

The application of blending obligations is more difficult in the air transport sector than in other activities, due to the international character of aviation. A mandate in some countries may involve fuel price differentiation and deviation of connecting traffic through airports not included in the mandate. Also, the airlines themselves may have to pay different amounts for fuel depending on the practical implementation of the mandate (by airports, by regions, by countries, by continents). This rises the convenience of applying provisionally mandates by airlines until the biofuel market is stabilised, the use of tradable certificates, as the RINs in the USA, is another possibility to be considered.

7.7 Conclusion for Chapter 7

Tax exemptions or subsidies seem to be easier to apply in the production and distribution phases than to the operator, leaving aside the already commented ETS case. At this moment

(March 2016), more than one year after the drop in oil prices, the gap between the price of the fossil kerosene and biokerosene is so dramatic that makes almost unthinkable to cover it with public money. Even in the previous 2014 situation, the most promising feedstocks appear to be more expensive than fossil kerosene. [Appendix 7](#) (Escobar et al. 2016) shows a comparison of prices used in ITAKA calculations, assuming industrial production levels of advanced biofuels. For reference, 2016 price of kerosene tonne is around 300€.

However, tax exemptions or financial grants for R&D and start-ups plants seems an acceptable option during the first years of second generation biofuels initial high scale production in a foreseeable future in which oil prices will have got back to the increasing trend. As civil aviation works on a set of internationally agreed rules, a general agreement on the treatment of the different categories of biofuel (first, second and third generation) would be needed to create a levelled playing field for the international airlines.

Fees, charges, and taxes are widely used incentives, which place per regulatory unit charge (or fee or tax) on pollution emissions or waste to reduce the overall quantity. The main drawback is that fees, charges, and taxes cannot guarantee a specific amount of pollution reduction, and only those who pollute will be penalised. Some examples include pollution taxes. (Adler & Gellman, 2012b)

INTENTIONALLY LEFT BLANK

CHAPTER 8

SUMMARY, CONCLUSION AND FUTURE STUDY

8.0 Introduction

This chapter discusses the main findings that contribute to the novelty of this study and to a deeper understanding of using biojet fuel and its impact on the maintenance performance and in turn, to promote the usage of biojet fuel in the civil aviation sector.

8.1 Summary of the previous finding

Previous research objectives can be concluded as two principal concern as followings:

1. This thesis presents the results of a forthcoming study of the feasibility of deployment of alternative jet fuels in commercial aviation from the MRO point of view. Detailed measurement of components will help MRO to analyse the engine system trend monitoring. At this point, the successful rate for maintenance of aircraft fuel system can be ensured, where it will be the core key of the presentable biojet fuel to the industries as the task will complete for Sustainability, Reliability, Availability, and Maintainability.
2. The work presented in this thesis also provides a review analysis on the background and current incentive rules and mechanisms to promote biofuel use in different parts of the world and particularly in the European Union. The effectiveness of those policies mentioned also has been laid out in previous chapter 7.

This research investigation has examined the issue of new alternative energy that utilises biojet fuel as a strategy to reduce cost and sustain the air transport industry. Researchers on the new economy of the renewable energy have become a top priority in the world of Airlines since it is complex and challenging to understand. On the other hand, environmental issues itself still have values to all of the other main transports, including air transport. In fact, the agenda of biojet fuel is among the sustainability concern approach.

The different incentive policies around the world are revised and compared, and some indications are offered on the most recommendable procedures that might be carried out in the near future.

Biofuels developments in an advance generation are a crucial evaluation in ensuring the sustainability of the aviation industries. Detailed information on the adaptation and adoption towards biojet fuel in the turbine aircraft fuel system suggests that viability of all the process regarding minimising the costing, especially in reducing the maintenance and operating costs. The reliability and maintainability will be the key factors for the success of deployment of commercialization of biojet fuel for aviation industries, especially in commercial aviation.

The urgencies, risks, and opportunities of this new alternative energy need to be broadened in various aspects for sustainability to reach and achieve its destination. Maintainability in the aircraft system, on the other hand, measures the right direction in supporting the quest to meet high sustainability goals by implementing biojet fuel. Moreover, biofuels may provide valuable economic opportunities to communities that can develop new sources of income – including in many developing nations.

Finally, the development throughout this new and clean energy in the aviation industry will drive more economy innovation around the globe, benefit the environment, create more job opportunities, and build the key factor to reach the maximum impact on sustainability as a whole.

In tackling the key issues of biojet fuel for aviation, it is necessary that all aspects be covered. This includes, but is not limited to, application, operation, and maintenance perspective. The effects on the relationship of each may be different and can lead to future prediction in prevention maintenance and towards the most crucial thing 'which is cost. As each relationship becomes more prevalent in the transition, sustainability needs to be established in examining the impact of all.

Throughout the four phase studies conducted, three important identification aspects that any framework of the Airlines impact in adaptation of bio jet fuel needs to take into account:

Positive and adverse effects of Airlines adaptation on biojet fuel, which must be addressed within a framework that includes the risks of:

- *Safety* that including the security of the engines, components, and ground support
- *The cost* of the new 'green fuel' and crucial costing for engine maintenance.
- Policy between Engine manufacturer and the Airlines, including the government policy incentive and mandate.
- *Time* factors affecting the maintenance routine A, B, C, D (HMMV's Check) including scheduled and unscheduled inspection. Moreover, time factors for Biojet fuel to be fully used.
- Awareness among different department in future bio jet fuel.

8.2 Recommendation

The recommendations below are based on the findings of this research study in which commercial aviation in adaptation towards biofuels as one of the resources for renewable energy are highlighted.

Airlines awareness on Environment, which consists of much more than just the profit to the Airlines but to compensate for the carbon tax. Evaluating the net impact of the technology life-cycle, operations of the aircraft including e.g. operating and use considerations including the end-of-life management.

The dynamics changes as an independent variable, an Airlines sector requires details analytical framework to be flexible. In regards to recent and future developments such as the full policies support globally. The scope will be referring to current maintenance program as an approach to planning and constructing the adaptation for the new alternative energy; therefore, it would be able to support airlines in saving cost and maintaining the

safety of the aircraft components in an aircraft engine. It would provide a reliable yet efficient way to examine and identify maintenance predictions.

8.3 Significant Contribution

The results of the main findings in this doctoral work present a significant contribution to knowledge and the industry in the maintenance field and energy policy where incentive and mechanism to promote biofuel for the future undertaking.

8.3.1 Maintenance view

From a maintenance point of view, based on overall phase being elaborated, open discussion can be made when maintenance does not pay much attention to this new alternative energy, as long as the authorities have approved. The most critical things that the new alternative energy has to meet are the fuel characteristics, the stability of the fuel, the maintenance of the fuel and the cost of the new fuel. For the same reason, kerosene-based fuel is used as fuel for airplanes instead of gasoline-based fuel, and the maintenance procedures for both are certainly different.

A direct impact of the maintenance program of this new alternative energy can easily be focused on economics cost benefit. As long as the price of petroleum remains high, the fossil source continues to be sufficient, the concerns about the environment persist, and then the interest in alternative jet fuels derived from non-petroleum sources will continue to grow. Despite the presence of technical hurdles and the growing necessity for further measurement and study on the costs and benefits, alternative jet fuels appear to be both technically and economically feasible in engine maintenance system because considerable momentum and coordinated work have resulted in recent years.

Most of the turbine maintenance is driven by the highest temperature against the average temperature which the parts is subjected. If the biojet fuel can improve and provide

uniformly burnt in the combustor section, the engine will last longer on the wing, and it is proving to have an immense maintenance cost benefit.

The fuel producers and fuel researchers need to ensure that the new fuel complies with the material to the standard of engine hot sections. Throughout many biofuel flight tests being conducted since 2008, most of the engines using biofuel have more optimum temperature compared to engines that used normal fuel. With this evaluation, it is acknowledged that in the long run, without a doubt, the use of biofuel will offer the benefit to the maintenance. With the reduction of fuel consumption and the specific requirements meet, prevention maintenance can safely be attained, and the components can reach beyond the standard life hours/cycle or even more. Above all, maintenance department will be able to allow the operator or airlines to identify whether using biojet fuel is beneficial and sensible in term of overall operating cost.

As discussed previously in Chapter 2, designer (manufacturer) and maintenance cannot be isolated. The airworthiness of the aircraft fuel systems needs to be ensured to enable the aircraft to fly and to prevent any malfunctions of the system throughout the flight. In this case, when the new alternative energy and the use of biojet fuel by airlines are mandated in the European countries, a closer alignment of goals is needed. The new policies and standard among engine manufacturers, the airlines, and the MRO, where engine contract such as total care and other service elements should be revised and be taken as priorities. Finally, it provides an update on the biofuels authorities and societies, and the progress to date enables the safe adoption and road acceptance of emerging alternative jet fuels to engineering and maintenance division.

8.3.2 Current incentive rules and mechanisms to promote biofuel use in the EU and their possible application to the civil aviation sector

Within the existing economic conditions, it is not feasible to achieve a Carbon Neutral Growth in the civil aviation industry without introducing alternative fuels with a smaller carbon footprint or reducing the activity of the sector drastically. While the use of low

carbon fuels like liquid hydrogen might be feasible in the long term, only drop-in biofuels have been demonstrated for short-term applications, but their present economic features make necessary some incentive measures, at least during the introductory phase.

As the drop-in biofuels for aviation have only been produced on an experimental scale, the potential cost of producing them in industrial conditions cannot be calculated now with a great level of accuracy, but it seems to be higher than fossil kerosene price in the most forecast. It implies the need for some market-based incentive to encourage the use of these products and allow the economic conditions to be produced at large scale.

There are different experiences in many countries of incentive schemes applied in other sectors, mainly in the automotive market, but none of them has been tested in the international field under common rules, something essential in the civil aviation field. This requires agreements on the type of feedstock, the level of blending and some targets, before selecting the applicable economic tools. It is essential to building up a widely accepted Monitoring, Verification and Reporting (MRV) procedures and a clear LCA assessment calculation for both fossil kerosene and alternative biofuels to quantify the achievable CO₂ savings, avoiding double counting, and to be used as the basis of a worldwide market-based mechanism.

The most promising approach to looking to other transportation sectors seems to be the subsidies through advanced tax management or offset mechanism, combined with a minimum level of mandatory blending, but other combinations are workable if a worldwide consensus is achieved a condition unavoidable in the civil aviation universe.

8.4 Future studies

In meeting future energy needs, it is important not only to ensure the maintainability of alternative energy but also the incentives rules and mechanisms to promote biofuel in the application in the civil aviation sector in EU and around the globe. Future studies should, therefore, concentrate to analyse more practical incentives that lead to the increasing number of biojet fuel usage among the industries and to investigate the outcome of the entire fuel systems, and to clarify the indenture level of the components once alternative energy is use. Integrating with the recent development of biojet fuel, economics barrier are

prominent. Particularly in the earlier stage, where its need to be articulated with the environmental goals and policies.

Further research is necessary to establish a clearer relationship between biojet fuel maintenance and cost-benefit analysis. There is no doubt the lends weight to the cost-benefit analysis when arguments of maintainability, sustainability, and reliability of the aircraft engine can be undoubted.

INTENTIONALLY LEFT BLANK

Appendices

Appendix 1-Maintenance Care

MANUFACTURER	INFORMATION
ROLLS ROYCE-TOTAL CARE	<ul style="list-style-type: none"> - More than 35 types of commercial aircraft and has almost 13,000 engines in service around the world - Products remain robust and underpins strong performance - The market leader and powers the fastest, the longest-range, and the largest business jets - Flexible & innovative services underpinned by digital capabilities - Traditional Fixed Price Overhauls or Time and Material support - Providing customers with choice and flexibility across the product lifecycle - Trent Service Network - Equipment availability : <ul style="list-style-type: none"> • 14 repairs and overhaul centers • 5000 engines and modules overhauled each year • Standardized Overhaul Process • Direct access to new and Rolls-Royce certificated spare parts • Hospital shops capability
PRATT AND WHITNEY - JSSI	<ul style="list-style-type: none"> - Largest independent provider of hourly cost maintenance programs for aircraft engines and airframes - The highest standard of service and excellence - Full range of hourly cost maintenance programs that stabilise aircraft maintenance costs and increase residual value - Many advantages over OEM aircraft maintenance programs - Traditional hourly cost maintenance programs - Stabilise your budget and enhance residual value - 24/7 access to the largest independent - Highly experienced technical and client services teams - Covers virtually every part, component, assembly and system of the airframe, including all parts and labour for scheduled and unscheduled maintenance - Available on virtually every make and model of business aircraft, including jets, turboprops, and helicopters - Provides comprehensive maintenance coverage for the Auxiliary Power Unit - For potential Alliance Members, working with JSSI affords many advantages, including: <ul style="list-style-type: none"> • Increase credibility • Increase revenue potential • Increase and added customer value
GE- GOLD CARE	<ul style="list-style-type: none"> - More than 30,000 engines in service - World leader in jet engine manufacturing, offering products for many of the best-selling commercial airframes - Leader in its class for performance, reliability and cost of ownership - Expertise in modular processing systems and ability to integrate third-party software led to high integrity systems - Take a lifecycle approach to developing electrical power solutions

	<ul style="list-style-type: none"> - Using data and analytics to identify ways to reduce operating costs, increase aircraft utilisation and improve the way to fly - Structure solutions through partnership and technology - Minimizes maintenance burden while maximising fleet efficiency - New, used serviceable & repaired material options <p>Specialized repairs</p> <ul style="list-style-type: none"> - Technology Upgrades - Overhaul service: <ul style="list-style-type: none"> • Most reliable supply of used serviceable material • Competitive turn-times • Material that maintains engine residual value - Reducing your cost and aircraft downtime - maximise asset value and take advantage of the full range of our world-class support - Optimising flight operation efficiency, operators can: <ul style="list-style-type: none"> • Measure and track savings, before and after, at fleet level – drill down per phase of flight • Change behaviour consulting for sustainable improvements
CFM - TRU ENGINE	<ul style="list-style-type: none"> - Provides flexible engine overhaul and repair solutions to meet your needs - Rate per Flight Hour (RPFH) programs to provide long-term support with cost per shop visit and time on-wing risk transfer - Customers can choose event-based pricing for engine overhaul and repair - Inefficient lease return condition shop visits may be minimized - OEM configuration assurance is in place to enable optimum product support and higher asset residual value - Comprehensive product support, original equipment manufacturer (OEM) warranty coverage, and the highest asset value. - Available for online ordering - Offers engine upgrades to enhance performance and reduce cost - Support you with vast technical expertise and global resources: <ul style="list-style-type: none"> • 24/7 customer support centers • In the field customer and product support teams • Customer technical training (hands-on and digital) • Engine monitoring and diagnostics • Data-driven fuel management and flight operations consultative services
MTU AERO ENGINE MAINTENANCE	<ul style="list-style-type: none"> - Most extensive engine portfolios in the world - Many years of experience - in maintenance, plus the design, development and production of new engines - Cost-effective maintenance thanks to alternative solutions and customised service offerings for all generations of engines - Handled almost 15,000 shop visits - Superior quality standards - Fast and predictable turnaround times - Cost-saving potential thanks to parts repair and used serviceable material solutions - Coordinated engine maintenance scheduling helps avoid bottlenecks - ECM permits maintenance planning as well as work scoping to be optimised for the long-lasting benefit. - ECM helps detect any abnormalities in engine operation in time thus preventing secondary damage from occurring - Custom-tailored services and MTU Maintenance's MRO expertise guarantee best

possible return of investment

- High-quality of service due to MTU Maintenance's in-house teardown capabilities, impressive repair technologies as well as technical and engineering expertise

- Guaranteed purchase of parts for natural consumption at MTU Maintenance

- MTU Maintenance's strengths at a glance:

- Excellent customer support
- One partner for all services
- Proximity to customers through a worldwide network
- tailor-made service solutions
- 24-hour on-call service
- All-inclusive full maintenance services

Appendix 2- Phase 2 questionnaires

Questionnaires form

This study is research conducted to a selected sample from a specific population identified. This survey is to obtain the data from individuals about the acknowledgement of the usage of biojet fuels in aviation and also its impact.

Section A: Personal Information

1. Age : _____
2. Gender ☐ ☐ Female
3. Position : _____
4. Length of Experience in Aviation: _____

For the section A, B and C on following questions, please circle only ONE for each question.

Section B: Personal knowledge about biojet fuels in aviation

No.	Question	Very High	High	Moderate	Low	Very low	Unsure
1	Do you know about biojet fuels usage in aviation?	5	4	3	2	1	0
2	Do you think biojet fuel is good to the environment?	5	4	3	2	1	0
3	Do you think biojet fuel is good to aircraft engine?	5	4	3	2	1	0
4	Do you think biojet fuel is good for reduced fuel cost?	5	4	3	2	1	0
5	Rate your thought on how profitable biojet fuel to airlines/ aviation company?	5	4	3	2	1	0

Section C: The feasibility of biojet fuels in aviation

No.	Question	Very Agree	Agree	Moderate	Disagree	Very Disagree	Unsure
1	Biojet fuels are safe to be used in aviation.	5	4	3	2	1	0
2	No modification required to the engine.	5	4	3	2	1	0
3	Level adaptation to biojet fuel will be easier	5	4	3	2	1	0
4	Low technical feasibility changing from normal fuel (Jet A/Jet A-1 to Biojet fuel)	5	4	3	2	1	0
5	Biojet fuel will be used widely around the globe in the near future	5	4	3	2	1	0

Section D: Impact of the usage of biojet fuels

No.	Question	Very High	High	Moderate	Low	Very low	Unsure
1	Better Environment	5	4	3	2	1	0
2	Better fuel cost	5	4	3	2	1	0
3	Increased engine performance	5	4	3	2	1	0
4	Saving Airlines for maintenance cost	5	4	3	2	1	0
5	Sustainable aviation industries can be achieve	5	4	3	2	1	0

Appendix 3- Consent letter

CONSENT LETTER:

Biojet fuel impact and its adaptation to aircraft maintenance.

Universidad Politecnica De Madrid, Spain and Universiti Kuala Lumpur

RESEARCH PURPOSES

The purpose of this research is to seek the engine/ aircraft expert in validating the document analysis.

INTERVIEW PROCEDURES

If you agree to participate in this research, you will be asked a few questions regarding your knowledge and experience of engine/ aircraft maintenance.

CONFIDENTIALITY

I will record the interview using audio tape and take handwritten notes. However, I will not expose your identity and privacy. Interview audio tape will be secured in electronic devices with a password and only accessible to the researcher and research's supervisor. Your interview information will be used for the final thesis presentation and investigation report only. Electronic data and physical notes will be destroyed after the research is finished.

RISK AND DISCOMFORT

If you found that this interview will cause risk and discomfort, you are free to discontinue the interview immediately with no prejudice.

BENEFIT OF RESEARCH

There is no compensation for the participation. However, your participation will help me to further my understanding of the relationship of biojet fuel to engine/ aircraft maintenance. If you have any question for this research, kindly contact me Hazariah Mohd Noh at hzariah.mnoh@alumnos.upm.es or kurtdxplane@gmail.com.

I have read the above information and agreed to participate in this research

Participant's signature:

Date:

Appendix 4- Phase 3 Interview Questions

The question

Interviews questions

- Q1 :** Please state your full name, education background and working experience in E&M.
- Q2 :** What are your roles and responsibilities in E&M?
- Q3 :** Did you aware of the alternative fuel? Moreover, Biojet fuel?
- Q4 :** Describe how biojet fuel might or might not reduce climate change and how can environmental concerns be addressed for current fuel specifications.
- Q5 :** What are some barriers for the organisation with regards to aviation fuel? Please explain.
- Q6 :** Do you think your company might transform traditional fuel to biojet fuel in near future? Describe your thought and what the expected outcome might be.
- Q7 :** What is your major concern in maintaining the engine using the biojet fuel?
- Q8 :** Which major concern do you think have high risk in the adaptation of biojet fuel in Aircraft engine maintenance? Can you name it in sequence?

Pilot questions

- PSQ1 :** In your opinion, do you think these ten questions above will provide applicable information for the following purpose of the study: To study the changes that biojet fuel will have on the aircraft engine maintenance, which will be through the perception of aviation management?
- PSQ2 :** In your opinion, do you think any questions should be deleted or added to achieve the purpose of the study? If so, please explain in details, so necessary for the interviewer to adjust the interview document accordingly.
- PSQ3 :** In your opinion, do you think the objective of the research is clear and you understand what the questions are trying to achieve?

Appendix 5- Consent Letter (Phase 4)

CONSENT LETTER:

Case Study on Biojet fuel flight test and its adaptation to aircraft maintenance.

Universidad Politecnica De Madrid, Spain and Universiti Kuala Lumpur

RESEARCH PURPOSES

The purpose of this research is to seek the engine/ aircraft expert in validating the document analysis.

INTERVIEW PROCEDURES

If you agree to participate in this research, you will be asked a few questions regarding your knowledge and experience of engine/ aircraft maintenance.

CONFIDENTIALITY

I will record the interview using audio tape and take handwritten notes. However, I will not expose your identity and privacy. Interview audio tape will be secured in electronic devices with a password and only accessible to the researcher and research's supervisor. Your interview information will be used for the final thesis presentation and investigation report only. Electronic data and physical notes will be destroyed after the research is finished.

RISK AND DISCOMFORT

If you found that this interview will cause risk and discomfort, you are free to discontinue the interview immediately with no prejudice.

BENEFIT OF RESEARCH

There is no compensation for the participation. However, your participation will help me to further my understanding of the relationship of biojet fuel to engine/ aircraft maintenance. If you have any question for this research, kindly contact me Hazariah Mohd Noh at hazariah.mnoh@alumnos.upm.es or kurtdxplane@gmail.com.

I have read the above information and agreed to participate in this research

Participant's signature:

Date:

CONSENT LETTER:

Appendix 6- Phase 4 Questionnaires

Directions: There are three sections in this questionnaire. Section 1 consists of question regarding your background. Section 2 explains the background of the research and questions regarding the finding. Section 3 contains questions on general understanding on biojet fuel. Thank you

Section 1 (Demographic Information) (Underlined)

- [illegible]

Section 2

Background of research.

Research title: The Effects of Biojet Fuel on Aircraft Engine: Perspective from Maintenance Personnel

The table below highlights three case studies on the effects of biojet fuel on aircraft engines

Case Studies	<p>A)</p> <ul style="list-style-type: none">- Air New Zealand Boeing 747-400 Rolls-Royce RB211-524G- 50% jatropha- Climb to FL 350, Mach 0.84 accels & decels, windmill engine restarts, starter-assisted engine relights, simulated missed approach, suction feed test <p>B)</p> <ul style="list-style-type: none">- Continental Airlines Boeing 737-800 CFM International CFM56-7B4- 7.5% jatropha, 2.5% algae 42% camelina,- Climb to FL390, Mach 0.78, accels & decels, windmill engine restarts, starter- assisted engine relights, simulated missed approach, suction feed test <p>C)</p> <ul style="list-style-type: none">- Japan Airlines Boeing 747-300 Pratt & Whitney JT9D-7R4G- 28% jatropha/algae- Climb to FL390, Mach 0.80, accels & decels, windmill engine restart, suction feed test. The only hydro-mechanical engine used for this series of flight tests.
---------------------	---

Figure 1 below shows storage stability – (water and biological growth)

Figure 1: Water composition in Biofuel flight test compares with conventional Jet fuel

In your opinion, will a smaller amount of water in Biojet fuel reduce the maintenance visit? Why?

In response to your answer, how will it affect the maintenance cost?

2. Figure 2 below presents the composition of the biojetfuel compares to Jet A fuel

Figure 2. The composition of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae comparing with Aromatics.

In your opinion, will the zero amount of aromatics in Biojet fuel affect the safety of the engine component? Why?

In response to your answer, how will it affect the maintenance cost?

Figure 3 below indicates the Fuel thermal stability in the Jet fuel compares to biojet fuel.

Figure 3: Thermal stability of Jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae

Higher fuel thermal stability contributes to higher combustion efficiencies. In your opinion, does it reflect the maintenance and safety? Why?

In response to your answer, how will it affect the maintenance cost? Why?

4. Figure 4 below displays the fluidity of the Jet A/A-1 fuel compares to biojet fuel.

Figure 4 : Fluidity of jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae

In your opinion, will higher freezing point affect engine safety? Why?

In response to your answer, will it prolong the maintenance visit? Why?

In response to your answer, how will it affect the maintenance cost? Why?

5. Figure 5 below shows the combustion properties comparison from Jet A to biojet fuel.

Figure 5 : Combustion of jet A/Jet A-1 compared to Jatropha, Jatropha/Algae, and Camelina/Jatropha/Algae

In your opinion, will zero smoke point increase the engine safety? Why?

In response to your answer, will it prolong the maintenance visit? Why?

In response to your answer, how will it affect the maintenance cost? Why?

In response to your answer, how will it affect the environment?

6. Figure 6 below shows the contaminants for Jet A/ A-1fuel compares to biojet fuel.

Figure 6 : Contaminants in jet A/Jet A-1 compared to Jatropa, Jatropa/Algae, and Camelina/Jatropa/Algae

In your opinion, will zero contaminants increase the engine safety? Why?

In response to your answer, will it prolong the maintenance visit? Why?

In response to your answer, how will it affect the maintenance cost? Why?

In response to your answer, how will it affect the environment?

Section 3

From the data shown in section 2, it demonstrates that the use of bio jet fuel does affect engine maintenance.

With regards to the use of aviation fuel, do you think Airlines should have a restriction on using biojet fuel in the future? Why?

Do you think the biojet fuel can reduce the airline fuel cost? Why?

Safety is vital in aviation. Do you think the airline should consider using the biojet fuel knowing that it will affect minor components of the aircraft engine? Why?

Do you think the airline industry will use biojet fuel in the near future? Why?

What are your major concerns with biojet fuel?

Do you think biojet fuel can be profitable for the aviation industry? Why?

APPENDIX 7- Biofuels Feedstocks

Potential future evolution of selected feedstocks biofuel production, compared with fossil kerosene (2014 economic conditions)

€/ton	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Salicornia	---	1037	1034	1032	1030	1027	1025	1022	1020	1017	1014	1012	1009	1007	1004
Camelina	873	871	869	866	864	861	859	856	854	851	848	846	843	841	838
Jathropha	---	1006	1004	1001	99	996	994	991	989	986	984	981	978	976	973
Microalgae	---	1793	1775	1757	1738	1720	1701	1682	1663	1644	1625	1605	1585	1565	1545
Kerosene	660	674	686	700	713	726	740	753	766	779	793	806	819	832	845

References

- A.Bauen, Jo Howes, L. B. (2009). Review of the potential for biofuels in aviation Final Reports For CCC.
- Adler, N., & Gellman, A. (2012b). Strategies for managing risk in a changing aviation environment. *Journal of Air Transport Management*, 21, 24–35. <http://doi.org/10.1016/j.jairtraman.2011.12.014>
- Agusdinata, D. B., Zhao, F., Ileleji, K., & DeLaurentis, D. (2011). Life Cycle Assessment of Potential Biojet Fuel Production in the United States. *Environmental Science & Technology*, 45(21), 9133-9143.
- Akbar, E., Yaakob, Z., Kamarudin, S. K., Ismail, M., & Salimon, J. (2009). Characteristics and Composition of *Jatropha Curcas* Oil Seed from Malaysia and its Potential as Biodiesel Feedstock, 29(3), 396–403.
- Alain Beck (Safran- Snecma). (2012). Engine Maintenance and Fuel Burn, IATA Maintenance Cost Conference Atlanta 17-18 October 2012. 3 / IATA MCC / / Atlanta. Retrieved from <http://www.iata.org/whatwedo/workgroups/Documents/MCC-2012-ATL/Day2/1150-1230-snecma-eng-mtce-vs-fuel-consumption.pdf>
- Alberici, S., Spottle, M., & Toop, G. (2014). Assessment of sustainability standards for biojet fuel Final report Assessment of sustainability standards for biojet fuel. Ecofys.
- Alonso, G., Benito, A., Lonza, L., & Kousoulidou, M. (2014). Investigations on the distribution of air transport traffic and CO₂ emissions within the European Union. *Journal of Air Transport Management*, 36, 85–93. <http://doi.org/10.1016/j.jairtraman.2013.12.019>
- Amizadeh, F., Alonso, G., Benito, A., & Morales-Alonso, G. (2016). Analysis of the recent evolution of commercial air traffic CO₂ emissions and fleet utilization in the six largest national markets of the European Union. *Journal of Air Transport Management*, 55, 9–19. <http://doi.org/10.1016/j.jairtraman.2016.04.006>
- ASTM D 1655. (2006). Standard Specification for Aviation Turbine Fuels, American Society for Testing and Materials. ASTM 2006
- ATAG. (2009). Beginner's Guide to Aviation Biofuels. Aviation. Retrieved from http://www.enviro.aero/ATAGGuide_lowres.pdf
- ATAG. (2011). Green Flight Time. Edition No. 6 Enviro Aero, 3–9.
- ATAG. (2012). Powering the future of flight. Air Transport Action Group.
- Awudu, I., & Zhang, J. (2012). Uncertainties and sustainability concepts in biofuel supply chain management : A review. *Renewable and Sustainable Energy Reviews* (Vol. 16). Elsevier Ltd. <http://doi.org/10.1016/j.rser.2011.10.016>

Azzam, H., Bonnefoy, P., Hansman, R. J. (2010) Investigation of fuel efficiency of the US Air Transportation network structure. 10th AIAA ATIO Conference. Fort Worth.

Bashan, Y., Moreno, M., & Troyo, E. (2000). Growth promotion of the seawater-irrigated oilseed halophyte *Salicornia bigelovii* inoculated with mangrove rhizosphere bacteria and halotolerant *Azospirillum* spp. *Biology and Fertility of Soils* (Vol. 32). <http://doi.org/10.1007/s003740000246>

Bailis, R. E., & Baka, J. E. (2010). Greenhouse Gas Emissions and Land Use Change from *Jatropha Curcas*-Based Jet Fuel in Brazil. *Environmental Science & Technology*, 44(22), 8684-8691.

Bauen, Ausilio; van den Heuvel, Eric and Maniatis, Kyriakos (2012): Biofuels Flightpath Workshop on Financial Mechanisms for advanced biofuel flagship plants. Brussels, 20 March 2012.

Bauen, Ausilio, and Kyriakos, Maniatis (2012): Biofuels FlightPath Workshop on upstream R&D and Innovation for biofuels in aviation. Milan, 18 June 2012.

Bauen, Ausilio, and Kyriakos, Maniatis (2012): Biofuels FlightPath Workshop on incentives for biofuels in aviation. Brussels, 20 June 2012.

Benito, A. (2008). Climate changes impact as a constraint to the air transport growth The European case. In *World Conference on Transport* (pp. 1–35).

Benito, Arturo (2012): Sustainable Air Transport: Governance and regulatory framework. Seminar on Strategies for Sustainable Development of Air Transport in Brazil. ANAC

Berti, M., Wilckens, R., Fischer, S., Solis, A., & Johnson, B. (2011). Seeding date influence on camelina seed yield, yield components, and oil content in Chile (Vol. 34). <http://doi.org/10.1016/j.indcrop.2010.12.008>

Birdlife European Division, European Environmental Bureau, FERN, Friends of the Earth Europe, Oxfam International, & Transport and Environment. (2009). Biofuels. Handle with care. An analysis of EU biofuel policy with recommendations for action. Brussels.

Boeing. (2008). Environment Report Boeing. (2008).

Boeing 737 Aircraft Maintenance Manual. (2000). System Review On Aircraft Maintenance Manual.

Boeing 737 Aircraft Maintenance Manual. (2000). Section 1. Introduction Maintenance, Scheduled Development, Program Checks, Maintenance Estimates, Maintenance Manhour Standards, Maintenance Performance Check,.

Bradburn, N., Sudman, S., & Wansink, B. (1990). Asking questions: A practical guide to questionnaire design. *Computers, Environment and Urban Systems*, 14(1), 72. [http://doi.org/10.1016/0198-9715\(90\)90052-U](http://doi.org/10.1016/0198-9715(90)90052-U)

CAAFI (2009). FRL Fuel Readiness Level CAAFI. Retrieved from http://www.caafi.org/information/pdf/FRL_CAAFI_Jan_2010_V16.pdf

CE Delft (2015): Assessing progress towards implantation of the ILUC Directive. 4. H38.1. Delft.

CFM 56. (1995). General engine data of CFM 56. Training. Retrieved from http://www.air.flyingway.com/books/engineering/CFM56-3/ctc-142_Line_Maintenance.pdf

CFM 56. (2000). Cfm56-7B Turbine Engine.

Chandrasekhar, B. (2014). Solving Aviation Fuel Complexities through Hyper Spectral Imaging Optimizing fuel maintenance, eliminating safety hazards and assuring the highest quality.

Colorado State University. (2016). Content Analysis as qualitative research. Retrieved May 5, 2016, from <http://writing.colostate.edu/guides/page.cfm?pageid=1307&guideid=61>

Cygnor, J. E. (1997). Subsection 9.19.1 AIRCRAFT FUEL PUMPS Retired Manager, Advanced Fluid Systems, Hamilton Sundstrand. IL Czarnecki: McGraw-Hill: New York, Chicago, San Francisco, Lisbon, London, Madrid, Mexico City, Milan, New Delhi, San Juan, Seoul, Singapore, Sydney, Toronto.

Daggett, D. L., Hendricks, R. C., Walther, R., & Corporan, E. (2007). Alternate Fuels for use in Commercial Aircraft. Most, (April), 1–8. Retrieved from <http://gltrs.grc.nasa.gov/reports/2008/TM-2008-214833.pdf>

Demirbas, A. (2008). Biofuels sources, biofuel policy, biofuel economy and global biofuel projections (Vol. 49). <http://doi.org/10.1016/j.enconman.2008.02.020>

Demirbas, A. (2009). Political, economic and environmental impacts of biofuels : A review. Applied Energy (Vol. 86). Elsevier Ltd. <http://doi.org/10.1016/j.apenergy.2009.04.036>

Dessens, O; Köhler, M; Rogers, H; Jones, R; Pyle, J. (2014): Aviation and climate change, Transport Policy, 34.

De-Rus, G. (2010). *Introduction to Cost-Benefit Analysis: Looking for Reasonable Shortcuts* (3rd Edition). Barcelona: Edward Elgar Pub (December 2010).

Dray, L. M., Schäfer, A., & Ben-Akiva, M. E. (2012). Technology Limits for Reducing EU Transport Sector CO2 Emissions. Environmental Science & Technology, 46(9), 4734-4741.

Dufferwiel, S. (2011). Alternative Aviation Fuels – Aromatics & Thermal Stability.

Eastin, I., & Bowers, T. (2014). Environmental Assessments of Woody Biomass- Based Jet Fuel Winter 2014, (January).

EBTP. (2009). Biofuels for Air Transport. Retrieved from <http://www.biofuelstp.eu/aviation-biofuels.html>

EC (2008). Directive 2008/101/EC of the European Parliament and the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community. Official Journal of the European Union, L(8), 3–21.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107–115. <http://doi.org/10.1111/j.1365-2648.2007.04569.x>

Environment Report (2006). The Future of Sustainability.

Escobar, A., Martín, R., Benito A. (2016). Análisis de la introducción a gran escala de biocombustible para la aviación en la UE. ETSIAE, Universidad Politécnica de Madrid.

EUROCONTROL (2015): www.eurocontrol.int/single-european-sky European Biofuels Technology Platform (2014): Biofuels policy and legislation. <http://bofuelstp.eu/legislation.html>.

European Environment Agency (2013): EU bioenergy potential from a resource-efficiency perspective. EEA Report No 6/2013.

European Union (2001a): Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market (27 September 2001), OJEU, 27.10.2001.

European Union (2001b): White Paper European transport Policy for 2010: time to decide. COM (2001) 370 final, Brussels 12 September 2001.

European Union (2003): Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport (8 May 2003). OJEU, 17.5.2003.

European Union (2009): Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (23 April 2009). OJEU, 5.6.2009.

European Union (2015): Directive 2015/1513/EC amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable fuels. Brussels, 19 September 2015.

European Union Commission (2008): Directive 2008/101/EC of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community.

European Union Commission (2011): Launch of the European Advanced Biofuels Flightpath. Brussels, June 2011.

European Union Commission (2014): Guidelines on State aid for environmental protection and energy 2014-2020. Brussels, 9 April 2014.

Federal Aviation Agency (2015): www.faa.gov/nextgen

Forsyth, P. Environmental and financial sustainability of air transport: Are they incompatible? (2011): *Journal of Air Transport Management*, 17.

Fortier, M.-O. P., Roberts, G. W., Stagg-Williams, S. M., & Sturm, B. S. M. (2014). Life cycle assessment of bio-jet fuel from hydrothermal liquefaction of microalgae. *Applied Energy*, 122, 73–82. <http://doi.org/10.1016/j.apenergy.2014.01.077>

Gegg, P., Budd, L., & Ison, S. (2014). The market development of aviation biofuel: Drivers and constraints. *Journal of Air Transport Management*, 39, 34–40. <http://doi.org/10.1016/j.jairtraman.2014.03.003>

Glenn, E. P., Brown, J. J., & Leary, J. W. O. (1998). *Irrigating Crops with Seawater*.

Glover, B. (2013). Boeing in MASBI 2013, Fuelling a Sustainable Future for Aviation. [Online]. http://www.masbi.org/content/assets/MASBI_Report.pdf (Assessed: 4th July 2014).

Gnansounou, Edgar; Panichelli, Luis; Dauriat, Arnaud, and Villegas, Juan David (2008): Accounting for indirect land-use changes in GHG balances of biofuels. Working paper Ref. 437.101. École Polytechnique Fédéral de Lausanne.

Goetz, A. R., & Graham, B. (2004). Air transport globalization, liberalization, and sustainability: post-2001 policy dynamics in the United States and Europe. *Journal of Transport Geography* (Vol. 12). <http://doi.org/10.1016/j.jtrangeo.2004.08.007>

Gorter, H. de, & David R Just. (2010). Featured Article The Social Costs and Benefits of Biofuels : The Intersection of Environmental, Energy and Agricultural Policy, 32(1), 4–32. <http://doi.org/10.1093/aepp/ppp010>

Gössling, S., & Upham, P. (2009). Climate Change and Aviation: Issues, Challenges, and Solutions. Earthscan. Retrieved from http://www.gci.org.uk/Documents/Aviation-and-Climate-Change_.pdf

Greg Hemighaus, Tracy Boval, Carol Bosley, Roger Organ, John Lind, Rosanne Brouette, Toni Thompson, Joanna Lynch, J. J. (2006). *Alternative Jet Fuels*. Chevron Corporation.

Group Transport Studies. (2008). Innovative Cooperative Actions of Research & Development in EUROCONTROL Programme CARE INO III Dynamic Cost Indexing.

Halog, A., & Manik, Y. (2011). Advancing Integrated Systems Modelling Framework for Life Cycle Sustainability Assessment. *Sustainability* (Vol. 3). Molecular Diversity Preservation International. <http://doi.org/10.3390/su3020469>

Harry A Kinnison. (2004). *Aviation Maintenance Management* (1 edition). ISBN978-0-07-180503-2 The McGraw-Hill Companies, Inc.

Hashimoto, N., Nishida, H., & Ozawa, Y. (2014). Fundamental combustion characteristics of Jatropha oil as alternative fuel for gas turbines. *Fuel*, 126, 194–201. <http://doi.org/10.1016/j.fuel.2014.02.057>

Heraghty, B., Elverton, J., Valastro, J., van Ewijk, F., Burgher, L., & Branighan, J. (2013). Feasibility Study of Australian feedstock and production capacity to produce sustainable aviation fuel. Mascot, Australia: Qantas Airways Ltd.

Hind, Peter (2014): The commercial use of biofuels in aviation. Regional International, March/April 2014.

Hileman, J. I., Stratton, R. W., & Donohoo, P. E. (2010). Energy Content and Alternative Jet Fuel Viability. Journal of Propulsion and Power, 26(6). <http://doi.org/10.2514/1.46232>

IATA (2001): Flight path to environmental excellence, Montreal.

IATA. (2009). Alternative Fuels Foreward 2009.

IATA (2009a). The IATA Technology Roadmap Report Montreal: IATA.

IATA Green Team. (2009b). ENVIRONMENT.

IATA (2009c). IATA ANNUAL REPORT 2009.

IATA (2010a). Annual Report. Retrieved from <http://www.iata.org/pressroom/Documents/IATAAnnualReport2010.pdf>

IATA (2009b). IATA Environment report (Vol. 2020).

IATA (2010b). International Air Transport Association Annual Report 2010 66 th Annual General Meeting Berlin , June 2010.

IATA (2011). IATA 2011 Report on Alternative Fuels.

IATA (2012). A global approach to reducing aviation emissions. First stop: carbon-neutral growth from 2020. Montreal: IATA.

IATA (2013). II. Resolution on the implementation of the aviation "CNG2020" strategy. Retrieved 22-06-2013, 2013.

IATA (2013a). Aviation Fuel Supply Model Agreement.

IATA (2013b). IATA 2013 Report on Alternative Fuels, (December), 78.

IATA (2013c). IATA 2013 Report on Alternative Fuels 8th edition Dec 2013. Retrieved from <http://www.iata.org/publications/documents/2013-report-alternative-fuels.pdf>

IATA (2014). Overview of Alternative Jet Fuels in 2014.

IATA (2015). IATA 2015 Report on Alternative Fuels.

IATA (2015a). Economic performance of the airline industry. Geneva.

IATA MCTF. (2013). Airline Maintenance Cost Executive Commentary.

ICAO (2004): Operational opportunities to minimize fuel use and reduce emissions. Circular 303, Montreal.

ICAO (2009). A summary of research and perspective ICAO on Alternative fuels.

ICAO (2010). ICAO Environment report.

ICAO (2013a): CAEP/9 agreed certification requirement for the aeroplane CO₂ emissions standard. Circular 337, Montreal.

ICAO (2013b): Consolidated statement of continuing ICAO policies and practices related to environmental protection. A38-18 General Assembly, October 2013.

ICAO (2016). Aircraft Engine Emissions. Retrieved May 10, 2016, from <http://www.icao.int/environmental-protection/Pages/aircraft-engine-emissions.aspx>

IEA. (2006). World Energy Outlook, International Energy Agency 2006. World Energy Outlook. Retrieved from www.iea.org/w/bookshop/pricing.html

International Energy Agency. (2010). Carbon Capture and Storage.

IPCC (1996). IPCC 1996 Chapter 6 RF of climate change. Retrieved from <http://www.ipcc.ch/ipccreports/tar/wg1/pdf/TAR-06.PDF>

Isa, S., Alwi, S., Rahman, R. A., Norsham, M., & Che, B. (2010). Paper Title : Advance Emission Control & Precision Agriculture ; CO₂ Sequestration Using Algae Integrated Management System. In 2010 International Conference on Chemistry and Chemical Engineering (ICCCE 2010) Paper (pp. 350–353).

ITAKA. (2012). Press Release Launch of ITAKA : EU Project to Support the Use of Sustainable Biofuels in Aviation Press release.

ITAKA (2016). www.itaka-project.eu

John D. Graham and Lorenz Rhomberg *The Annals of the American Academy of Political and Social Science* Vol. 545, Challenges in Risk Assessment and Risk Management (May 1996), pp. 15-24

Jaeger, W. K., & Egelkraut, T. M. (2011). Biofuel economics in a setting of multiple objectives and unintended consequences. *Renewable and Sustainable Energy Reviews* (Vol. 15). Elsevier Ltd. <http://doi.org/10.1016/j.rser.2011.07.118>

Jain, S., & Sharma, M. P. (2011). Thermal stability of biodiesel and its blends: A review. *Renewable and Sustainable Energy Reviews* (Vol. 15). Elsevier Ltd. <http://doi.org/10.1016/j.rser.2010.08.022>

James D. Kinder and Timothy Rahmes. (2009). Evaluation of Bio-Derived Synthetic Paraffinic Kerosenes (Bio-SPK).

Janic, M. (2002). Methodology for assessing the sustainability of an air transport. *Journal of*

Air Transportation, 7(2), 1999–2001.

Jeppesen Sanderson. (2009). A&P Technician Powerplant Textbook (5th Edition). Jeppesen.

Jiang, H. (2013). Key Findings on Airplane Economic Life Key Findings on Airplane Economic Life Associate Technical Fellow Aviation System Analysis Boeing Commercial Airplanes Key Findings on Airplane Economic Life Boeing Commercial Airplanes.

Joanna Schroeder. (2014). Honeywell Green Jet Fuel Flies FIFA Teams. June 17, 2014.

Karassik, I. J., Messina, J. P., Cooper, P., & Heald, C. C. (2001). Pump Handbook Fourth Edition. <http://doi.org/10.1002/aic.690220632>

Kant, P., & Wu, S. (2011). The Extraordinary Collapse of Jatropha as a Global Biofuel. *Environmental Science & Technology*, 45(17), 7114–7115.

Kar, R., Bonnefoy, P. A., & Hansman, R. J. (2010). Dynamics of Implementation of Mitigating Measures to Reduce CO₂ Emissions from Commercial Aviation (No. ICAT-2010-01). Cambridge (MA): Massachusetts Institute of Technology Cambridge, MA.

Khandelwal, B., Roy, S., Lord, C., & Blakey, S. (2014). Comparison of Vibrations and Emissions of Conventional Jet Fuel with Stressed 100% SPK and Fully Formulated Synthetic Jet Fuel. *Aerospace*, 1, 52–66. <http://doi.org/10.3390/aerospace1020052>

Kivits, R., Charles, M. B., & Ryan, N. (2010). A post-carbon aviation future: Airports and the transition to a cleaner aviation sector. *Futures*, 42(3), 199–211. <http://doi.org/10.1016/j.futures.2009.11.005>

Koivisto, R., Wessberg, N., Eerola, A., Ahlqvist, T., Kivisaari, S., Myllyoja, J., & Halonen, M. (2009). Integrating future-oriented technology analysis and risk assessment methodologies. *Technological Forecasting and Social Change*, 76(9), 1163–1176. <http://doi.org/10.1016/j.techfore.2009.07.012>

Kousoulidou, M., & Lonza, L. (2016). Biofuels in aviation: Fuel demand and CO₂ emissions evolution in Europe toward 2030. *Transportation Research Part D: Transport and Environment*, 46, 166–181. <http://doi.org/10.1016/j.trd.2016.03.018>

Kramer, R. (2006). Project Management Handbook.

Henk, H., Kramer, R., Sesink, L., & Joris, Z. V. (2006). *Project Management Handbook*. San Francisco, CA: DANS.

Kuhn, P. (1970). Airborne observations of contrail effects on the thermal radiation budget. *J. Atmos. Sci.* 27.

Lave, L. (1987). Health and safety risk analyses: information for better decisions. *Science*, 236(4799), 291–295. <http://doi.org/DOI: 10.1126/science.3563509>

Law, C. K. (2012). Fuel Options for Next-Generation Chemical Propulsion. *AIAA Journal* (Vol. 50). <http://doi.org/10.2514/1.J051328>

- Lawler. (2011). *Management Reset- Organizing for sustainable effectiveness*. Jossey-Bass.
- Lee, D. S., Fahey, D. W., Forster, P. M., Newton, P. J., Wit, R. C. N., Lim, L. L., Sausen, R. (2009). Aviation and global climate change in the 21st century. *Atmospheric Environment*, 43(22-23), 3520–3537. <http://doi.org/10.1016/j.atmosenv.2009.04.024>
- Liu, G., Yan, B., & Chen, G. (2013). Technical review of jet fuel production. *Renewable and Sustainable Energy Reviews* (Vol. 25). Elsevier. <http://doi.org/10.1016/j.rser.2013.03.025>
- Lane, Jim (2013): Biofuels mandates around the world. *Biofuels Digest*, December 31, 2013. <http://www.biofuelsdigest.com>.
- Marsh, G. (2008). Biofuels: aviation alternative? *Renewable Energy Focus*, 9(4), 48-51.
- Macintosh, A., & Wallace, L. (2009). International aviation emissions to 2025: Can emissions be stabilised without restricting demand? *Energy Policy*, 37(1), 264–273. <http://doi.org/10.1016/j.enpol.2008.08.029>
- Maurice, L. Q., Lander, H., Edwards, T., & Iii, W. E. H. (2001). Advanced aviation fuels : a look ahead via a historical perspective. *Fuel* (Vol. 80).
- MASBI (2013), *Fuelling a Sustainable Future for Aviation*. [Online] http://www.masbi.org/content/assets/MASBI_Report.pdf
- Maxwell Smith. (1979). *Aviation fuels*.
- Mitchell, Donald (2008): A note on rising food prices. World Bank Policy Research Working Paper no. 4682. Washington DC.
- Mintzberg, H. (1979), "An emerging strategy of 'direct' research", *Administrative Science Quarterly*, Vol. 24, pp. 580-9
- Morgan, M. G. (1998). Commentary: Uncertainty Analysis in Risk Assessment. *Human and Ecological Risk Assessment: An International Journal*, Volume 4(Issue 1), pages 25–39. <http://doi.org/10.1080/10807039.1998.11009680>
- Morrell, P. (2009). The potential for European aviation CO2 emissions reduction through the use of larger jet aircraft. *Journal of Air Transport Management*, 15(4), 151–157. <http://doi.org/10.1016/j.jairtraman.2008.09.021>
- Moubray, B. J. (1995). *Maintenance Management - A New Paradigm*. Aladon Ltd.
- MTU Aero Engine. (2012). *Technical Memorandum Project FAIR* (Vol. M 12 TEA-0).
- Multi Commodity Exchange. (2008). *Aviation Turbine Fuel*, (November).
- Naik, S. N., Goud, V. V., Rout, P. K., & Dalai, A. K. (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews* (Vol. 14). <http://doi.org/10.1016/j.rser.2009.10.003>

- Nair, S., & Paulose, H. (2014). Emergence of green business models: The case of algae biofuel for aviation. *Energy Policy* (Vol. 65). <http://doi.org/10.1016/j.enpol.2013.10.034>
- Ninni, A. (2010). Policies to support biofuels in Europe: The changing landscape of instruments. *AgBioForum*, 13(2), 131–141. <http://doi.org/http://www.agbioforum.org/>
- Noh, H., Alonso, G., & A. Rahman, Noraida (2015). Green Renewable Energy – Risk Need to Be Tackled in Going Green for Air Transportation. *Applied Mechanics and Materials*, 747(1pcc 1996), 325–328. <http://doi.org/10.4028/www.scientific.net/AMM.747.325>
- Noh, H., Alonso, G., Nair, S., & Dahdi, Y. (2015). Biofuels: their emergence and implications for sustainability in aviation, 206, 103–111. <http://doi.org/10.2495/ESS140091>
- Noh, H. M., Benito, A., & Alonso, G. (2016). Study of the current incentive rules and mechanisms to promote biofuel use in the EU and their possible application to the civil aviation sector. *Transportation Research Part D: Transport and Environment*, 46, 298–316. <http://doi.org/10.1016/j.trd.2016.04.007>
- Noh, H., & Zulkifli, N. (2012). Short-Term and Long-Term Feedstock Bio Jet Fuel for Green Environment of Air Transport in Climate Change Awareness. In *Applied Mechanics and Materials* (pp. 572– 577). <http://doi.org/10.4028/www.scientific.net/AMM.225.572>
- Nrel, A. M., & Retired, R. P. N. (2008). The Future of Liquid Biofuels for APEC Economies.
- Phyllis Pollack. (2013). SWOT analysis. Retrieved from <http://www.mediate.com/articles/PollackPbl20131115.cfm>
- Peeters, P., (2013). Trends in technology and fuel efficiencies and consequences for stringency setting, ICAO CAEP WG3 Information Paper, Madrid.
- Pilzecker, Andreas (2011): Future of Biofuels: An agricultural policy perspective. European Biodiesel Board General Assembly. Brussels, 17 November 2011.
- Polit, DF, Beck. CT & Hungler, BP. 2001. *Essentials of nursing research: Methods, appraisals, and utilization*. 5th edition. Philadelphia.: JB Lippincott.
- Raffi Babikian, Stephen P. Lukachko, I. A. W. (2002). The historical fuel efficiency characteristics of regional aircraft from technological, operational, and cost perspectives. *Journal of Air Transport Management*.
- Ramani, M. (2009). *Investment Opportunities in the Greener Flight to Future*. Frost & Sullivan.
- Ribeiro, K., `Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D. S., ... Zhou, P. J. (2007). Transport and its infrastructure. In *Climate Change 2007: Mitigation. The contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, N.
- Rizki. (2009). JAL Flight Brings Aviation One Step Closer to Using Biofuel. Retrieved from <https://rizkibeo.wordpress.com/2009/03/15/jal-flight-brings-aviation-one-step-closer-to->

using-biofuel/

Robert Wall. (2015). Airbus Racks Up More 2014 Jet Orders Than Boeing - Wall Street Journal. Retrieved from <http://www.wsj.com/articles/airbus-racks-up-more-2014-jet-orders-than-boeing-1421142005>

Roll Royce. (1996). The Jet Engine 5th Edition (Fifth edit). Renault Printing Co Ltd Birmingham England B44 8BS.

Roll Royce. (2007). Gas turbine technology Jet Propulsion - Power through the ages (VCOM13797 ed.). Rolls-Royce plc 2007.

Rosillo-calle, F., Teelucksingh, S., & Seiffert, M. (2012). The potential and Role of Biofuels in Commercial Air Transport- Biojet fuel.

Rye, L., Blakey, S., & Wilson, C. (2010). Sustainability of supply or the planet: a review of potential drop-in alternative aviation fuels. *Energy & Environmental Science*, 3(1), 17-27.

SAE. (2002). Reliability-centered Maintenance. Satish Lele. (2011). Algae: An Oil Crop of Future. Retrieved from <http://svlele.com/algae.htm>

Schäfer, A; Waitz, I. (2014): Air transportation and the environment, *Transport Policy*, 34.

Schäfer, A., Heywood, J. B., Jacoby, h. D., & Waitz, I. A. (2009). *Transportation in a climate-constrained world*. Cambridge, MA: MIT Press.

Sgouridis, S., Bonnefoy, P. A., & Hansman, R. J. (2011). Air transportation in a carbon constrained world: Long-term dynamics of policies and strategies for mitigating the carbon footprint of commercial aviation. *Transportation Research Part A: Policy and Practice*, 45(10), 1077–1091. <http://doi.org/10.1016/j.tra.2010.03.019>

Simone, N. W., Stettler, M. E. J., & Barrett, S. R. H. (2013). Rapid estimation of global civil aviation emissions with uncertainty quantification. *Transportation Research Part D: Transport and Environment*, 25, 33–41. <http://doi.org/10.1016/j.trd.2013.07.001>

Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource technology* (Vol. 101). <http://doi.org/10.1016/j.biortech.2009.11.046>

Sims, R., Mercado, P., Krewitt, W., Bhuyan, G., Flynn, D., Holttinen, H., et al. (2011). *Integration of Renewable Energy into Present and Future Energy Systems*.

Singh, J., & Gu, S. (2010). Commercialization potential of microalgae for biofuels production. *Renewable and Sustainable Energy Reviews*, 14(9), 2596-2610.

SMIC. (1971). *Inadvertent Climate Modification, Report of the Study of Man's Impact on Climate*. MIT Press, Cambridge, Mass., US.

Subramaniam, A. (2010). Risk Management Framework Process, Tools & Techniques to Minimise Risk Exposure. Retrieved from

<http://www.slideshare.net/anandsubramaniam/risk-management-framework>

Sundaram, S., Strachan, I. G. D., Clifton, D. A., Tarassenko, L., Campus, O. R., & Drive, R. (2011). Aircraft Engine Health Monitoring using Density Modelling and Extreme Value Statistics 2 Feature Extraction and Visualisation. The Sixth International Conference on Condition Monitoring and Machinery Failure Prevention Technologies 919.

Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977-6988.

Stephens, E., Ross, I. L., King, Z., Mussnug, J. H., Kruse, O., Posten, C., et al. (2010). An economic and technical evaluation of microalgal biofuels. *Nat Biotech*, 28(2), 126-128.

Stratton, R. W., Wong, H. M. Hileman, J. I., (2010). Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, PARTNER Project 28 report, June 2010.

Streubert, HJ & Carpenter, DR. 1995. Qualitative research in nursing: Advancing the humanistic imperative. Philadelphia: Lippincott.

Sustainable Aviation Fuel Users Group (SAFUG) (2010): Governments' unique role in sustainable aviation biofuel. August 2010.

Vecchiet, Alessia (2011): European biofuels blending obligation. Esse community, August 14, 2011. <http://www.essecommunity.eu>.

Vera-Morales, M., & Schäfer, A. (2009). Fuel-Cycle Assessment of Alternative Aviation Fuels. Manchester: Manchester Metropolitan University.

Vessia, Oyvind, Riis Nielsen, Kare; Grassi Giuliano and Urbancic, Nusa (2013): The Future of Biofuels as an alternative fuel for the transport sector. Workshop of the European Parliament Intergroup. Brussels, 16 October 2013.

Vorster, S., Ungerer, M., & Volschenk, J. (2012). 2050 Scenarios for Long-Haul Tourism in the Evolving Global Climate Change Regime. *Sustainability*, 5(1), 1-51.

Wiesenthal, Tobias; Leduc, Guillaume; Christidis, Panayotis; Schade, Burkhard; Pelkmans, Luc; Govaerts, Leen, and Georgopoulos, Panagiotis (2009): Biofuel support policies in Europe: Lessons learnt for the long way ahead. *Renewable & Sustainable Energy Reviews*, Part 13, pp. 789-800.

Wanyan, X., Zhuang, D., & Xu, Z. (2010). Thermal Analysis for Fighter Aircraft Fuel System. 2010 Asia-Pacific Power and Energy Engineering Conference. Ieee. <http://doi.org/10.1109/APPEEC.2010.5448364>

Weselby, S. (2012). IATA Maintenance Cost Conference – Fuel Burn vs. Maintenance Costs Breakdown – IATA Assessment.

Woodward. (2005). Aircraft Engine Systems Components Maintenance Manual (Vol. 440).

Yacobucci, Brent D. (2012): Biofuels Incentives: A Summary of Federal Programs. Congressional Research Service R40110. Washington 11 January 2012.

Yin, R. K. (2009). Research: Design and Methods (Chapter 2) (pp. 25–66). SAGE.

Y.S. Lincoln and E.G. Guba, Naturalistic Inquiry, Beverly Hills: Sage, 1985

Zschocke, A. (2015). HBBA Study : Effects on emissions test using SIP fuel (farnesane)

Zschocke, A., & Scheuermann, S. (2012). High Biofuel Blends in Aviation (HBBA) ENER/C2/2012/ 420-1 Interim Report.

Ziolkowska, Jadwiga; Meyers, William H., Meyer, Seth and Binfield, Julian (2010): Targets and Mandates: Lessons learned from EU and US biofuels policy mechanisms. AgBioForum, Volume 13, Issue 4, pp. 398-412.

Zwicker, P. Eickemeier, G. Hansen, S. Schlömer & C. von Stechow (Eds.), IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (pp. 609-706). Cambridge, UK; New York, NY, USA: Cambridge University Press.

Resume

Hazariah Mohd Noh

PhD Researcher/ Lecturer

Universiti Kuala Lumpur- MIAT

hazariah.mnoh@alumnos.upm.es / hazariah@unikl.edu.my - (+60 192496682)

Professional Attributes

Currently Ph.D. Student for 'Doctorado en Ingenieria Aeroespacial.'

Research on an adaptation of future alternative energy (Bio jet fuel) for aviation towards the impact on commercial aircraft maintenance/ performance.

Lecturer for Airframe and Powerplant section

(Feb 2004 –present) University Kuala Lumpur of Malaysian Aviation Institute Technology (UniKL- MIAT). Responsible for delivering aircraft maintenance standard and procedures subject to Department Civil Aviation Malaysia (DCA, FAA, CAA) and European Aviation Safety Agency (EASA).

Skills

Language skills

English, Malay- Fluent

★★★★★

Italian- Basic

★★★★★

Spanish- Intermediate

★★★★★

Computer skills

Microsoft Windows operating systems and Microsoft Office packages, Mind Mapping, AutoCAD, Adobe Illustrator.

Experience

Volunteer in 2nd European Gender Summit 2012 European Parliaments, Brussels
29th-30th November 2012

- Participate in organizing the event with 420 peoples from 58 countries
- Responsibilities in handling the material for the presentation
- Helping with the conference's main information desk and counter
- Coordination on others logistical matter
- Contribution in making the event successful

An Intern in Airbus Military-EADS CASA, Madrid March-July 2009 [Project Management]

- Process Improvement in 23 Black Belt Project
- (SSC)Supplier Support Condition's identification
- Procurement in Order's and Supplier's
- GRESS(General requirement for Equipment's and system Suppliers) Identification

Experience

Volunteer in 2nd European Gender Summit 2012 European Parliaments, Brussels

29th-30th November 2012

- Participate in organising the event with 420 peoples from 58 countries
- Responsibilities in handling the material for the presentation
- Helping with the conference's main information desk and counter
- Coordination on others logistical matter
- Contribution in making the event successful

An Intern in Airbus Military-EADS CASA, Madrid March-July 2009 [Project Management]

- Process Improvement in 23 Black Belt Project
- (SSC)Supplier Support Condition's identification
- Procurement in Order's and Supplier's
- GRESS(General requirement for Equipment's and system Suppliers) Identification

University Kuala Lumpur –Malaysian Institute Aviation Technology (UniKL-MIAT) Feb/04-Present **LECTURER**

Responsible for teaching Propulsion and aircraft systems for a theoretical and practical lecture in the following Engines; Roll Royce V2550, Allison 250- APU, Continental Engine o-040, Lycoming o-540. Cessna 310, Cessna 150, Hawker 500, Hughes Helicopter 500, Sky Hawk Fighter, Lycoming T-53 (turboshaft) William Research Corporation.

Malaysia Airlines System(MAS)

July/00-Dec/01

AIRCRAFT MECHANIC

Participated in carrying out aircraft maintenance on Boeing 737- 200, -400, - 500, Boeing 747-400, Boeing 777-200, and Airbus A330 on A, B, C, D & H MV Checks for both Airframe and Powerplant.

Education

Universidad Politécnica de Madrid, Spain -2012

Master Universitario en Ingenieria Aeroespacial

(Master Thesis) Air transportation and relationship to climate change` `an overview of biofuels roadmap."

Universidad Politécnica de Madrid, Spain Sept. 2008-Sept.2009.

Universita Di Pisa, Italy. Oct2007-July 2008

European Master in Aeronautics and Space Technology (EuMAS). (MSc. Aeronautics)

(Master Thesis) The process Improvement in Aircraft Maintenance Management- cost perspective.

Northrop Rice Aviation Institute, California, USA.

Bachelor of Science in Aircraft Maintenance Engineering Technology

Graduate Dec/03 Grades: Second Class Upper

Associate of Applied Science in Aircraft Maintenance Engineering Technology

Graduate Dec /02 Grades: Second Class Upper

Certification

Certified Mendeley Advisor and Trainer

Beginner, Intermediate, Advance application for Mendeley as Research Tools [2015]

Certified Primary Instructor for Power plant by UniKL-MIAT.

Theory / Practical for Turbine Engine System. [July 2004]

Certified Aircraft Mechanic on civil aircraft given by Malaysia Airlines System.

Certified on Turbofan, Turboshift, Turbojet and Turboprop Engines. [Dec 2000]

Certified Aircraft Mechanics with 737-200,300,400,500 series type rating level 2

Malaysia Airlines Training School, Subang, Malaysia. [Dec 2000]

Certificate of Aviation Maintenance Technology Airframe and Powerplant Mechanics

Mara Northrop Rice Institute, Jasin Malacca, Malaysia.[July 2000]

Professional Training AND Courses attended

Aviation Technical Courses

- Boeing 737 old generation series (2000)
- Basic Digital Avionic Level II (2000)
- Gas Turbine Engine Fundamental(2000)
- OSHA (2001)
- CFM 56 Gen Fam (2016)

Management Development Courses

- Team Building(2001)
- Pedagogy Course(2004)
- Seven Habits of Highly Effective People (2005)
- Mentoring Programme (2007)
- CAeD training(2010)
- Time management & Prioritising skills (2015)

Communications Training

- Technical Communication(2002)
- Motivation and Psychology Skills (2003)
- Teaching Constructive Communications (2004)
- English Technical Aviation Communications Training Workshop (2006)
- NLP for beginner (2010)
- Delivering High Impact Business presentation (2014)
- Presentation for Highly effective people From 7 Habits (2015)
- NLP Training in Child Educational (2016)

Research Workshop

- Research Methodology for Post Graduate Studies(2009)
 - Camsol Training for Simulation(2010)
 - STRG Seminar UniKL-MIAT(2010)
 - Literature Review-Backbone of Research(2010)
 - Writing skills for Research(2010)
 - SIMPLER (Research Seminar) 2010
 - Introduction to Maple for Academics(2011)
 - Mendeley and applications (2012)
 - Zero draft thesis (2013)
 - Fast thesis writing (2014)
 - Preparation for VIVA MPWS (2014)
 - Ph.D. Mosaic (2015)
 - Mendeley Trainer (2015)
 - Journal Publication for Academics (2016)
 - Postgraduate symposium (2016)
-

Achievement/ Paper Presented

1. Members of El'Aero Verdes team, successfully team for a second round of the **Fly Your Idea Airbus go green in climate change 2008-2009**.
 2. One among the hundred selected participant for the **Global Humanitarian- Climate Change**, Geneva, Switzerland 2009.
 3. Project title '**Combating carbon footprint- Aviation Biofuel**' being chosen as a top project and being handed to Kofi A.Annan in Copenhagen General Climate Change meeting March 2009.
 4. GE Europe competition '**Make your campus greener**' successful team for second round 2009.
 5. Paper '**Algae-based biofuel business plan for aviation**' Bioenergy 2009, Finland.
 6. Paper '**Green energy alternatives in aviation**' presented at Engineering Congress Application or Necessity 2009, Kuwait.
 7. Work presentation '**Aviation Carbon Footprint - Cheap and clean biofuel solution for greener Environment**' Presented Erasmus Mundus Alumni Conference- Let's Redefine the terms (Green Communication) 2010- Bordeaux, France.
 8. Working Paper '**Engine Ground Run procedure for Modified Mock up Allison 250 Turboshift Engine**' presented at UniKL MIAT conferences 2010, Malaysia.
 9. Paper '**Green Environment of Air Transport- Technology (Biofuel overview)**' presented in RIDITA III, Madrid, 2011.
 10. Paper '**Short-term and Long-term Feedstock's Bio Jet Fuel for Green Environment of Air Transport in Climate Change Awareness**' presented in Aerotech IV 2012, Kuala Lumpur, Malaysia published in Periodical of Applied Mechanics and Materials Vol. 225 in 2012 with the title AEROTECH IV – Recent Advances in Aerospace Technologies.
 11. Paper presented'' **Green renewable energy – Risk need to be tackled in going green for air transportation**'' ICSEBS 2014, Bali Indonesia. Published in Applied Mechanics and Materials Vol. 747 in 2015 with the title Advances in Green Science, Engineering and Built Environment
 12. Paper presented "Air Transport- **The new alternative energy towards aircraft maintainability and sustainability**" Energy and Sustainability 2014, Malaysia. Published in books; Energy and Sustainability V: Special Contribution ISBN 978-1-78466-095-6 WIT Transaction, UK
 13. Team leader for **Malaysian hospitality "Fly Your Idea Airbus 2015"** successful team for the second round. Project title "**Elevating sustainable aviation biojet fuel prosperity.**"
 14. Paper accepted "**Urgencies in Aviation Biojet fuel towards sustainability**" SETNC, October 2015, Bangi, Malaysia. Will be Publish in Journal Science Engineering Technology.
 15. Grant awarded 2015-2017 (113,000 RM) from Malaysian Government to conduct fundamental research in Readiness level of biofuel for commercial Aviation usage. Title approved "**Biojet fuel Adaptation Framework in Aviation: Readiness Level Perspective.**"
 16. Paper accepted "**Study of the current incentive rules and mechanisms to promote biofuel use in the EU and their possible application to the civil aviation sector**". Published in Journal of Transportation Research Part D: Transport and Environment.
-

INTENTIONALLY LEFT BLANK