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# MASTER THESIS

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## RENEWABLE ENERGY FOR SUSTAINABLE TOURISM IN SMALL AVIATION INDUSTRY:

Case Study of Light Aircraft / Rotorcraft  
Flight Operators in Japan

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Graduation Date:  
September 2015

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## **Dedication**

*I dedicate this work to my father, who is my source of inspiration for never fearing to challenge the truth and stay relentless foreseeing and building the better future.*

## **Acknowledgements**

I would like to thank all the researchers, innovators, pioneers and aviation fanatics who dedicate their lifetime to make flying more accessible and continue to seek for ways to sustainably coexist with our planet. Additionally, special credits to Ritsumeikan Asia Pacific University for field research funding, my research supervisor Prof. Malcolm Cooper, Dr. Zach Favors for assistance with the Li-Ion study and Mr. George Bye for outstanding achievements and aviation support.

## **Abstract**

The key objectives of this research is to present financial, managerial and technical insights into the small aviation tourism industry as a tool to substantially increase long-term profitability and raise a new level of safety standards for environmental sustainability in Asia Pacific region by utilizing renewable energy perspective.

The data gather through two field research studies conducted in Japan of small aircraft / rotorcraft flight operators and in California, US of electric aircraft symposium revealed market vector development towards gradual transition to electric propulsion, in some cases via hybrid systems. Further, Japan was chosen as a potential testing ground for implementing sustainable renewable energy solutions based on critical factors of safety awareness, technological advancement, fuel resource dependence, geographical positioning and national pilot shortage.

Comprehensive analysis showed that energy density, which can be stored in the different modifications of Li-ion batteries, is still far from the normal diesel engine in terms of weight and cost equilibrium, while its thermal fault for transportation applications remains to be an issue; yet, an improved electric propulsion technology should eventually transform small and medium aviation into it's cleaner and environmentally kindlier version.

## Legends

DOC	Direct Operational Costs
LCC	Low Cost Carriers
IATA	International Air Transport Association
MLIT	Ministry of Land, Infrastructure and Tourism
MTSAT	Satellite-Based Augmentation System
GSE	Ground Support Equipment
CCO / CDO	Continuous Climb / Descend Operations
ICAO	International Civil Aviation Organization
NEDO	The New Energy Development Organization
UN / NGO	United Nations / Non Government Organization
MEA	More Electric Aircraft
NO <sub>x</sub> / H <sub>2</sub>	Nitrogen / Liquefied Hydrogen
CDA	Continuous Descend Approach
RNP	Required Navigation Performance
FAA	Federal Aviation Authority
CTL / GTL / STL	Coal-To-Liquid / Gas-To-Liquid / Sunlight-To-Liquid
GDP	Gross Domestic Product
JCAB	Japan Civil Aviation Bureau
RPK	Revenue Passenger Kilometers
L/D	Lift to Drag Ratio
EU / EC	European Union / European Commission
FADEC	Fully Authority Digital Engine / Electronics Control
TAM	Total Available Market
SAM	Serviceable Available Market
SOM	Serviceable Obtainable Market
VFR	Visual Flight Rules
FSTD	Flight Simulator Training Device
AEAC	Aero Electric Aircraft Corporation
AVGAS	Aviation Grade Fuel
HP	Horse Power
TBO	Time Between Overhaul
PLM	Product Lifecycle Management
LIB	Li-Ion Battery
CNT	Carbon Nano Tube
LNG	Liquefied Natural Gas
NTSB	National Transport Safety Board
FMEA	Failure Mode Effect Analysis
FTA	Fault Tree Analysis
VTOL / STOL	Vertical Takeoff Landing / Short Takeoff Landing
UAV	Unmanned Aerial Vehicle
UNHAS	United Nations Humanitarian Air Service
WFP	World Food Program
UNDS	United Nations Department of Safety
OIOS / DFS	Office of Internal Oversight Services / Department Field Support
ATS	Air Transport Section
PD/DM	Procurement Division/Department of Management
OOSS	Office of Central Support Services

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## Chapter 1

### Renewable Energy for Sustainable Tourism in Small Aviation Industry

#### 1.1 Research Background

For the past three decades technological advancement has considerably contributed to the volume of passengers and cargo flights conducted daily, and Asia has been one of the most rapidly growing regions in terms of accessible travel points and destinations by air. While general aviation companies are strictly bound to pre-scheduled routes managed by international corporations with high-risk business models and headquarters overseas, small<sup>1</sup> domestic and regional charters are much more flexible in service, less costly in maintenance, and are adaptable to tailoring for wide range of tourism<sup>2</sup> operations.

The relationship between aviation and tourism is highly dependable yet vulnerable, and the rapid growth of air travel demand highlights the necessity for complex strategies to achieve synergies between both industries. Air transport and tourism are currently bound up in a cycle that will generate ever-increasing environmental and social impacts unless essential transformations in their operation and organization occur (Janelle and Beuthe 1997). As a result, several authors have acknowledged that fundamental changes in technology, operation, design and financing are needed if air transport and tourism are to become more sustainable (Greene and Wegener 1997:177; Paterson et al. 2006).

<sup>1</sup> The term light aviation involves aircraft primarily limited in size, weight (up to 5,670 kg), range, passenger capacity, useful load onboard, and total engine power output. In general, such aircraft require considerably shorter runways for takeoff and landing, operate within lower speed limits, and are cheaper to maintain. In addition, particular types, properly equipped, can be operated on non-standard runways and may substitute plain fields, water (for hydroplanes) or snow-covered areas due to its initially lower weight and speed.

<sup>2</sup> With the expansion of social networks, Internet and technology, unknown and unexplored destinations are becoming more popular and exposed to the access of growing population. Apart from main cities of interest (where access by air is largely covered by global aviation corporation) there is an emerging demand for points to reach out that are impossible technically and/or unfeasible financially for air giants, yet is much easier for a small operator, especially if it is an area of islands, mountains, forests etc.



## 1.2 Objectives

Although airliners have considerably higher impact due to their size and volume of operations, for the key purposes of this research the light aircraft/rotorcraft aviation sector was chosen due to its adaptable nature. The important task is to construct a commercially feasible, eco-oriented flight operation business framework, and apply to this renewable energy concepts that may substantially reduce environmental impacts.

Since criticism of dependence on limited fuel resources will continue to negatively affect direct operational costs (DOC) in the airline industry, application of alternative energy usage is the next effort to create more sustainable equilibrium between a growing industry and an already endangered environment, if inevitable air-travel demand is to be met. Hence, the central focus of this study is to examine the potential to implement renewable energy technology in the aviation industry, and to evaluate the possibility to completely revise airline strategy by crafting an eco-air flight operation model with a zero-emission prospect.

## 1.3 Research Questions and Structure

The key issues to be examined in detail and further discussed are:

1.3.1. An overview of existing air-tourism policies in Japan, financial indicators of current status for the past decade, yearly tourist flow by air transport:

- a) What are the trends and projected tendencies of air transport industry in Japan?
- b) Which transportation segments do small aviation operators occupy, and why do they act as a critical link to the future of general aviation?
- c) How imposed governmental directives address environmental challenges in the aviation industry?
- d) What are the key factors that influence the link of aviation tourism to an effective environmental policy?

1.3.2 (Field Study 1). What market segment is occupied by light aircraft / rotorcraft air operators in Japan (see Appendix A), and what is the current state of operation with regards to compliance with existing tourism and environmental policies:

- e) What is the economic relationship between aviation fuel, price structure and CO<sub>2</sub> emissions in aviation industry in Japan?

1.3.3 (Field Study 2). Exploration of current renewable energy solutions in the aviation industry and how their potential usage might be implemented into Japan's environmental sustainability and tourism policies:

- f) What practical applications of renewable energy concept in aviation industry currently exist (industry analysis from global perspective)?
- g) What are the political, economic and technical challenges that restrain the small aviation industry from achieving a smooth sustainable transition?
- h) How Japan's technological advancement, geographical positioning and current condition of aviation industry could be utilized to achieve effective transition toward more sustainable air transportation and environmentally friendly air-tourism practices?

1.3.4. A Case Analysis of the United Nations Humanitarian Air Service (UNHAS). What are the current challenges of UNHAS and how Japan's example could influence first steps toward transition for sustainable aviation?

## **1.4 Field Research Rationale**

The factors to be examined are:

- Company overview, operational procedures and target customer
- Cost structure, resource supply, DOCs, available governmental subsidies (if any)
- Geographical positioning, main competitors, agreements with business and government organizations (if any)
- Safety procedures and requirements
- Federal aviation regulations
- Airway availability and congestion of the airspace
- Track of environmental impact

## 1.5 Methodology

The field study segment will be conducted in three phases. Firstly, to outline a detailed understanding of how flight operations are conducted, a clear image of the small aviation industry's role in the economy and impact on the environment can be achieved by further examination of five elements:

- a) Business type and profitability
- b) Resource usage matrix
- c) Environmental impact rating
- d) Governmental policy and regulation limitations, and
- e) Company's desired development vector

Qualitative data collection, as well as an investigation of short and long-term growth priorities from selected companies management and operation staff was performed by organizing interactive interview sessions. Acquired material will serve as a baseline for the exposure of critical problems and potential improvement solutions in terms of the five above-mentioned factors.

Secondly, a holistic investigation of breakthrough innovations in the small aviation industry is conducted to understand its current situation and future tendencies as well as reveal political, economic and technical constraints that might disrupt or otherwise impact transition to sustainable environmental air-transport operations.

The third part focuses on the development of an innovative strategic framework for one selected type of light aircraft/rotorcraft flight company, by crafting a model for energy efficient eco-air flight operation practices that concentrates on the gradual application of renewable energy solutions for each operational segment. This developed case study is expected to work as an innovative business strategy model illustrating cost-effective, eco-air approach with environmentally sustainable resource-preserving solutions.

## 1.6 Academic Background

The theory of *Diffusion of Innovation* was chosen as a supporting background for research that is largely concentrated on procurement of technological innovations in the small aviation industry for a more sustainable future. Diffusion of Innovation theory is often regarded as a

valuable change model for guiding technological innovation where the innovation itself is modified and presented in ways that meet the needs across all levels of adopters. It also stresses the importance of communication and peer networking within the adoption process (Cjini.net 2015). Renewable energy technologies constitute a techno-economic system that is radically different from conventional systems, in terms of density, structure, regulatory and management practices. Consequently, a strategy that focuses on selected niches should aim at the integration of the innovation dimension into a policy for renewables (Tsoutsos & Stamboulis 2005). Through four main elements of diffusion of technological innovations (innovation, communication channels, time and social system) adopter distribution tends to follow S-shaped curve over time to approach normality and can be partitioned in five adopter categories: innovators, early adopters, early majority, late majority, and laggards (Rogers 2010). In this research application of the renewable energy concept in small aviation industry represents the diffusion stage of innovation transition toward early adopters with normal distribution diffusion pattern.

### **1.7 Expected Outcomes**

Air travel constitutes a significant part of the environmental impact of tourism, while tourism generates considerable demand for air transport (Graham 2012). A practical guide of how to reach and implement a new standard for environmentally sustainable small aviation tourism operations is the leading expected outcome of this paper. Furthermore, with in-depth understanding of financial, technical and managerial impacts on aviation operations, the developed business framework and case study is expected to play a decision-making role in applying eco-air strategy solutions to use for both private and government flight operators in Asia.

### **1.8 Summary**

There is a strong yet vulnerable relationship between aviation and tourism, which is affected by increased demand in air travel and growing volume of passengers that continues to negatively impact the environment. The key objective of the research is to construct commercially feasible, eco-oriented flight operation business framework by applying renewable energy concepts that may substantially reduce environmental impacts such as CO<sub>2</sub> emissions, toxic fuel wastage, and water pollution as well as address noise issues. The first field study was conducted to investigate the economic relationship between aviation fuel, price structure and CO<sub>2</sub> emissions in the industry in Japan. Next, the findings in the

second field study focus on exploration of current renewable energy solutions in the aviation industry. Based on the theory of diffusion of innovation, the expected outcome of this research is to find how renewable energy can be applied in the small aviation industry, and to what extent it may benefit Japan's environmental sustainability and eco-tourism policies.

## **Chapter 2**

### **A Small Aviation Business Model**

#### **2.1 Definition**

There are various definitions that can be applied to describe the small aviation business model. As mentioned in Chapter 1, small (or often referred as light) aviation is flight service operations limited in aircraft size, weight, range, passenger capacity, and useful payload onboard as well as total engine capacity. It may be used for one specific purpose or combination of operations depending on location, the regulations in use, and the type of business applied. In general, quite the same grouping concept may be applied to medium and large size aircraft, with the exception of technically impractical or impossible combinations (such as parachute jumping from jet aircraft). Nevertheless, small aviation operations may also be described as operations where restricted size and weight aircrafts are utilized for various purposes where to achieve that particular purpose an actual flight has to be conducted, following required performance specifications and stated aviation regulations.

#### **2.2 Key Characteristics of Small Aviation**

Small aviation operations can be separated into number of groups by type of service and specific purpose of utilization:

- a) Pilot training facilities: flying schools that provide professional pilot course training to obtain student, private or commercial pilot licenses. Often, such facilities also offer instrument rating and multi-engine rating courses (which is the next step before flying large jets in the airlines under air transport pilot license). Such facilities vary in fleet's type and size; often have their own runway and maintenance staff on the ground. Normally, (same as in driving schools) aircraft in pilot facilities are designated only for training purposes, therefore, they have strictly regulated airworthiness procedures, requirement to be checked by maintenance after each flight and are restricted for only specified type of flights. The revenue of such business model comes mostly from both ground schooling and specific flight hours with or without supervising instructor onboard as well as supporting documentation assistance.

- b) Charter flights: another section of operations come from regular or on-request commercial air transport of passengers and / or cargo to designated destinations. Depending on geographic location, such destinations often are either hardly accessible by other means of transport, or available runways can accept only size and weight restricted aircrafts with short landing and takeoff distances. In many cases, charter flight operators might also offer such services as aerial photography, scenic flights or simply private flights to do a wedding proposal.
- c) Specific use aerial services: such flights often vary in type of business operation and can cover aerial mapping, news reporting, traffic observation, video production and more. However, there are no clear restrictions that prohibit operating under combination of several purposes at the same time.
- d) Business aviation: commercial flights are relatively close to charter operations with the exception of highly prioritized on-demand model. Normally, large companies and corporations have their own fleet and utilize it for whatever purposes required by the company. (In addition, aircraft for business aviation represent a particular social VIP status, which may be observed through outstanding interior of the aircraft).
- e) Medical services: medical operations often act as a byproduct of expanded operations of large hospitals and other medical facilities that permits to transport urgent patients to the point in short time (mostly by helicopters with helipads on the roofs of the buildings). Additionally, same aircrafts / rotorcrafts may also be used for search and rescue operations during national disasters (earthquakes, tsunamis, fires, landslides), emergencies, industrial breakdowns and where other type of danger exists and evacuation is required.
- f) Aerial sport activities: these are aircrafts that are used for different sport activity applications such as parachute jumping, sky diving (small aircraft for general aviation may be used with little technical adjustments, for example, door removal and additional step installation for jumpers) as well as aerobatics and air racing (specially constructed aircrafts with more powerful engines, re-enforced airframe and adjusted weight to withstand high G loads).

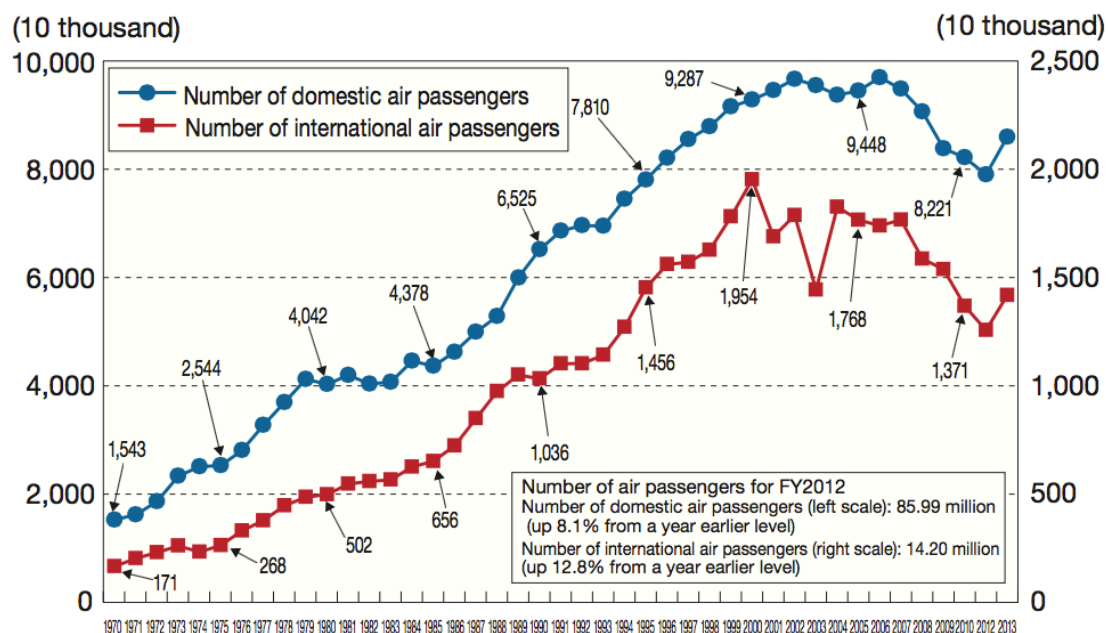
- g) Agricultural application: often privately owned and are used for farm crop dusting / spraying or other agricultural purposes. Additionally, with proper certification such activities as banner towing or brochure dropping might also be seldom practiced.

### 2.3 Trends in Air Transport business: Japan

Japan's air transport experienced its peak in FY2006, however, due to the global economic recession followed by the Great East Japan Earthquake there has been a substantial downslope in the volume of domestic and international passengers. Only in FY2012 was the industry able to recover, to achieve nearly 86 million of domestic passengers with more than 14 million international travelers (total ~100 million for year 2012) (Figure 1). Another strong economic drive was triggered by the first LCC (Low Cost Carrier) entry by Peach Airlines in the Japanese market, followed by Vanilla Air, Jet Star Japan and Spring Airlines.

According to the International Air Transport Association (IATA), the global airline industry has achieved a growth rate of approximately 5% year on year in the last 30 years (Belobaba 2009). Most of the growth is attributable to the emergence of low-cost carriers that control 25-30% of the Global market. The greatest challenge facing these companies has been low profit margins, which are even further affected due to unpredictable contributing factors such as Ebola outbreak in Africa, transnational terrorism and volcanic eruptions (Gomes 2014).

**Figure 1: Developments in the Number of Air Passengers (Japan – Based Airlines)**



Source: "Air Transportation Statistical Yearbook", MLIT



Price pressure continues to be a factor resulting in a drop in prices and yields have consistently dropped. For airlines to remain vibrant cost control is an ever-growing concern, especially such as high fuel charges and costly delays at overcrowded airports that impact negatively on the airlines bottom lines. The way individual commercial airlines react to and implement strategies across the globe will determine carrier performance and their capability to survive.

## **2.4 Aviation Development Initiatives**

In 2013 report of MLIT (Ministry of Land, Infrastructure and Tourism) Japanese government is continuing to take initiative action to improve aviation industry and further develop air transportation within the region. Recently, with the global warming and CO2 emissions level becoming a center of attention as a critical and highly sensitive environmental issue, MLIT challenges to implement new effective practices to further advance Japan's transport infrastructure. In aviation several key vectors have been observed:

- a) Supporting transport to and from remote islands and enhancement and optimization of airport operations

To secure air transport to and from remote islands, the MLIT subsidizes aircraft purchase costs, running costs and MTSAT Satellite-based Augmentation System (MSAS) receiver purchase costs and eases landing fees and aviation fuel and fixed property taxes for common air carriers serving remote islands. Additionally, future efforts will be directed at driving airport management reforms through integrated management of aviation business and non-aviation business, utilization of private knowledge and funds, etc. (Mlitgo.jp 2015).

- b) Accelerating the reception of business aviation

In October 2013, the Ministry took an initiative to ease authorization procedures for foreign-registered business chartered airplanes entering Japan. MLIT granted them a permission to conduct air services between the domestic flight segments connecting their routes under the condition that stated regulatory requirements have been met. However,

c) Initiatives to reduce CO<sub>2</sub> emissions in aviation

According to the report, MLIT continues to promote the use of ground power units for airplanes and ecological cars such as GSE vehicles as part of Eco Airport activities. As well as participate in the "Asia and Pacific Initiative to Reduce Emissions" such as improved air traffic control management to achieve efficient air traffic flow to face growing air traffic congestion issue. Furthermore, MLIT also makes an effort to be a part of global initiatives to reduce CO<sub>2</sub> emissions from the aviation industry.

d) The Promotion and Dissemination of Alternative Fuels in Aviation (Biojet fuels)

Alternative fuels are made from materials such as algae, plants such as jatropha and camelina, used cooking oil or municipal waste, and compared to fossil fuels, may lead to the reduction of CO<sub>2</sub> emissions over the entire life cycle including the growth process of the raw materials (Mlit.go.jp 2015). The International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) have set forth the objectives of: (1) improving fuel mileage by 1.5% each year up until 2020, (2) becoming carbon neutral by 2020, and (3) reducing CO<sub>2</sub> emissions by 50% compared to 2005 levels by 2050. In Japan, The New Energy and Industrial Technology Development Organization (NEDO) has been conducting research on the manufacture of bio jet fuel derived from microalgae (2010 - 2011, 2013 - 2016) (Asiabiomass.jp 2015).

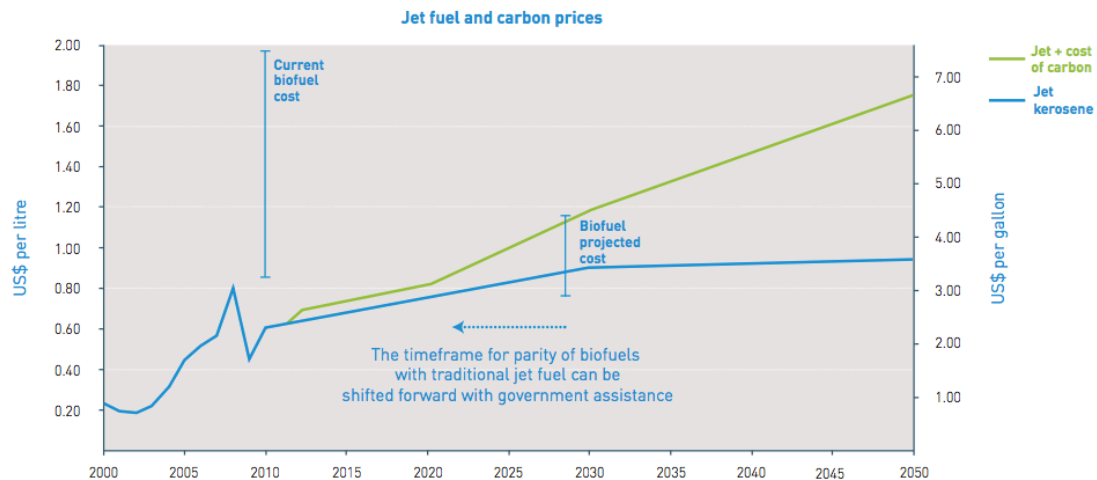
According to the European Biofuels Technology Platform, the aviation industry is unlikely to rely on just one type of feedstock. Aircrafts will be powered by blends of biofuels from different types of feedstock along with jet fuel. Biomass sources for advanced bio-jet fuels include oil crops such as jatropha and camelina, waste fats and oils, and, in the longer term, biomass sugars, algae and halophytes (Biofuelstp.eu 2015). (See Figure 2 for jet fuel and carbon prices for future projections on biofuels).

## **2.5 Performance Based Navigation (PBN)**

PBN remains the sector's highest air navigation priority and a key enabler of more flexible use of the airspace, expanded use of continuous climb and continuous descent operations (CCO/CDO), improved route spacing and de-confliction, and environmental benefits through associated noise and emissions reductions. As the global warming issue becomes more important, many researchers have been trying to reduce aircraft fuel consumption. In

2011, more than 676 million tons of carbon dioxide (CO<sub>2</sub>) was emitted. The goal is to reduce by two the CO<sub>2</sub> production of 2005 by 2050 (Patrón, Berrou & Botez, 2015).

**Figure 2: Jet Fuel and Carbon Prices**



Source: ATAG, 2012.

The ICAO Air Navigation Report therefore consists of qualitative and quantitative data and analysis and addresses relevant air navigation system performance areas (see Patrón, Berrou & Botez for complete list on current fuel consumption optimization research).

## 2.6 Operation Research in Aviation Industry

(Based on review of: Yu, G., "Operations Research in the Airlines Industry," Kluwer Academic Publishers, 1998)

Due to enormous demand from management of air transportation operations to gain a competitive advantage in the market, airlines are turning to advanced optimization techniques to develop mission-critical decision support systems for management and control of airline operations. The product offered by airlines is represented by flights that carry passengers or cargo from various origins to various targeted destinations. As a rule, the marketability of the product is judged by the timeliness, accuracy, functionality, quality, and price of the service. The customers place their choices on the following criteria:

- Flexible schedules
- On-time flights
- Safety

- Satisfactory in-flight services
- Proper baggage handling
- Convenient ticket purchases

The direct resources required to build the service include aircraft, crew, and airport facilities runways, gates. Additional supporting resources such as maintenance bases, fuel services, food services, and crew training facilities are also required.

Being in nature a highly competitive industry, airlines face competition not only from peer air carriers, but also from ground transportation companies such as buses, trains, ships, and rental cars. The use of personally owned vehicles and small size aircrafts also poses some increasing threat. To meet new competition challenges (especially in the online environment), and to provide a product with high quality and low cost, airlines spend a tremendous amount of resources and effort to generate profitable and cost-effective fare classes, flight schedules, fleet plans, aircraft routes, crew pairings, gate assignments, maintenance schedules, food service plans, training schedules, and baggage handling procedures. Nevertheless, another level of complexity is added for several reasons:

- a) The major causes are inclement weather, aircraft mechanical problems, crew sickness, and fuel shortages. A small disruption in one place will snowball through the network, which is often uncertain and lack flexibility for backup.
- b) Tight FAA restrictions on aircraft maintenance, crew legality, runway availability, security, etc.
- c) The large operational scale requires resource availability on each end, which adds another difficulty in planning and expenses cutting processes.

From a technological perspective, computing speed is now fast enough to solve complex, large-scale, real-time problems; in addition, cost is low enough to justify return on investment. The solution is optimization, which is the key aspect described in the book.

Conclusion 1: while organizational and planning problems in a small aviation industry is less complex and might execute higher degree of flexibility, the majority of exiting barriers and limitations are similar to any aircraft. Therefore, some of suitable optimization techniques applied in the airline industry should be carefully examined and re-designed in terms of functioning algorithms for further planning and operations.

## 2.7 Aviation and Tourism

*(Based on review of: "Graham, A., Papatheodorou, A. and Forsyth, P., "Aviation and Tourism: Implications for Leisure Travel," Ashgate Publishing Ltd, 2010)*

While exposing common challenges faced by airline operators to attract growing number of tourists and generate proper supply to access as many new destinations as possible, the main theme of this book emphasizes necessity to the two way linkages which exist between aviation and tourism industries. Ensuring that the interconnection of both is fully understood during decision-making process is vital for successful operation. The wide mix of authors who worked on the book also provides a wide range of cultural aspects, which undisputedly influence performance of organization processes.

The author examines in depth the nature of leisure travel demand from economical perspective and assessing the implications of serving this demand for the aviation industry. By identifying key influencing factors and exposing potential demand elasticity, further methodology is presented to forecast leisure demand for air travel and travel preferences by region, while applying various marketing techniques and market segment analysis. Further, the analysis of governmental and environmental policies influence on both industries is presented. While discussing supply issues and organization strategies, few sections are dedicated to discuss air charter and small-scale tour operator's performance, especially in EU. Next, implication of future development of air travel in tune with cultural / local tourism expansion is presented as a stepping stone for further research, stressing on potential trends of tourism expansion and power of leisure policies injected by selected governments.

Conclusion 2: the link between tourism and aviation is a valuable starting step, and understanding of already existing research point will assist in diverting concentration of unresolved issues, while at the same time challenging offered solutions for a new level of efficiency.

## Chapter 3

### 3.1 Research Linkage for Effective Environmental Policy

Effective policy structuration is a highly complex process that through its social, environmental and economical circles is continuously subjected to numerous of tangible as well as indefinable influence factors. While series of methods have been developed and partially applied since the explosion of industrial revolution to account for and manage quantifiable environmental impact issues, yet the immense portion of unpredictable, hence, uncontrollable reasons in different ways shift the vectors of desired policy outcomes. Policy itself, as a socio-economic reflection of public on surrounding environment, has various definitions that mostly depend on the author's background, position and perspective, therefore, may be vague, specific, or combination of both. Nevertheless, to further aid this discussion, the following environmental policy is proposed:

*“Competitive market-value based instrument to gradually transform public's behavior toward sustainable co-existence with the environment”.*

### 3.2 Concept Description and Limitations

The primary purpose of this chapter is to develop a draft proposal for potentially effective research conduct in overall aviation industry and it's further transition into sustainable environmental practices, based on five crucial considerations:

#### a) Synergy of Research

There is exponentially increased capability of research development and data accumulation due to recent outburst of technological advancement and information processing systems.

#### b) Populous Burst

Unstable population growth rates due to cumulatively progress in basic medical resources.

#### c) Global Information Network

Access to information available through worldwide media and Internet means, high

potential to reach yet undeveloped regions.

#### d) Distinctive Technology Craft

Power of technology development and innovative solutions available through mutual collaboration of know-how holders and innovators raises the potential scope of the achievements.

#### e) Environmental Business Model

Re-evaluation of environmental policy projects as a competitive market-based product available for participating stakeholders gradually through all social dimensions, starting on local level.

According to the nine Rockström's boundaries (Rockström 2009) circle of "a safe operating space for humanity" (see Note 1), initial estimates indicated that at least three of the nine boundaries have already been crossed for climate change, the nitrogen cycle, and biodiversity loss and that resource pressures are moving rapidly toward the estimated global boundary for several others too (Worldwatch Institute 2013). While majority of rapidly diminishing resource exploitation and its distribution lies under the control of corporations and numerous political layers of corruption and bureaucracy, importance of collaborative public power, effective research development practices and recent trends of information technology spread are yet another favorable factors for policy makers to utilize successful transition in social behavior towards environment. Consequently, marketization of an environmentally sustainable lifestyle with the value-add approach is proposed and further discussed as a transitional framework for next targeted research course and effective socio-environmental policy framework structuration.

### 3.3 Why there is a gap?

The main complication during theory application in practice arises due to unforeseen issues that contribute to the gap between academia world of clear problems, massive data and concrete solutions, and, on the other side, policy makers with floating influence factors from public, political and economic aspects. According to Stocking (Stocking 1995), in a commentary on why research findings are not used by commissions in the UK, for

example, identifies four reasons:

- The research is not there;
- Many managers are not “knowledgeable”;
- Public health (and others) does not act as a product champion of knowledge;
- Change is more difficult than expected.

Additionally, Lomas’s (2005) findings portray a clearer picture of core discrepancies between research academia and policy makers:

- 1) Researchers and policy makers consider each other’s activity as generating products instead of engaging in processes.
- 2) Researchers and Policy makers consider different valuables in their decision- making process. While scientific research concentrates on a clearly measurable problem and seek a concrete solution, policy makers tend to take into account other variables such as interests, ideology, values and opinions.
- 3) Substantial differences in reward and incentives system, especially concerning funding and utilizing governmental budget for the particular program.
- 4) Communicability with the audience. For researchers academic complexity (including language and terminology) is considered to be in favor, the policy community has much wider range of audiences varying in background, culture, needs and beliefs.

Consequently, above “cultural” misapprehensions between two communities and their lack of appreciation for one another provide additional complications in finding an efficient balance. Therefore, due to numerous safety requirement and regulation layers, aviation industry is one of the least responsive to scalable change, without mentioning tremendous financial constrains with in every segment of operations.

### **3.4 Policy Development Issues**

Though there are numerous policy frameworks available for each sector (public, environmental, economical etc.), neither may efficiently exist without application of the key



principles such as defining a problem, course formulation, adoption methods, implementation process that is followed by parallel or post-factum evaluation. Regardless the framework type, the criticism (mostly relative to the human factor) is often mentioned as weak chain parts that crucially influence the potential outcome of the proposed policy (Howlett 2002):

- 1) Limited analysis and status quo issue with conventional alternatives;
- 2) Close interrelation between goals and impact from indirect influence factors;
- 3) Over-analysis and concentration on the problem rather than solution finding and damage management;
- 4) Inability to cover the whole matrix of potential outcomes and projections;
- 5) Complication to foresee all consequences as well as reach a fully proven decisions and evaluate thoroughly weight of all available alternatives.

In addition, Canadian workshop findings (CHSRF 2005) on relationship between research and policy-making process:

*“Linkage between researchers and decision makers should be reached through leadership from the research funding agencies and supported by “knowledge brokers”, with full understanding of potential costs involved”.*

### **3.5 Synergy of Research**

The primary consideration in this section is to indicate the necessity to utilize complex research data resources simultaneously for initial problem definition processes and environmental policy agenda formulation. While specific research statistics may appear to be highly appealing in theory and are further funded by associate resource supplier, the practice reveals that number of introduced policy programs fail or underperform depending on a scale. As an example, efforts to synthesize a comprehensive theory of domestic policy implementation have generally failed (Maloney, Jordan & McLaughlin 1994). While acquiring immense volumes of environmentally relevant data through comprehensive research process is vitally important for particular policy development processes, understanding of socio-cultural and forecast of economic incentives for the majority of stakeholders (general public as the largest sector) is a critical step in long-term continuity of the policy to be proposed. Public acceptance of certain renewable energies in Germany

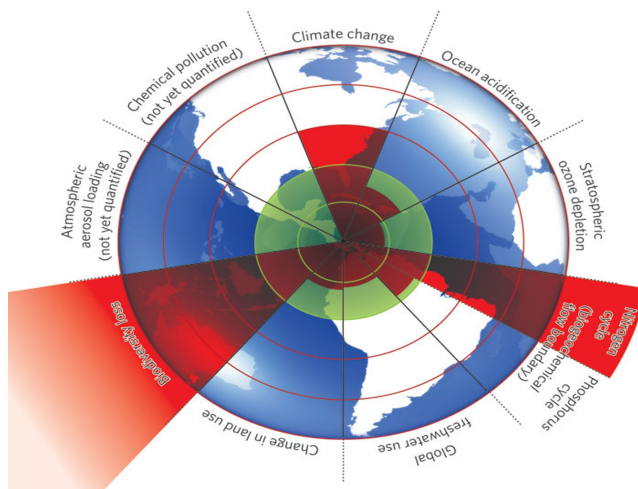
(grid-connected larger PV ground-installed systems, biomass plants and wind turbines) from a socio-scientific perspective is a good example (Zoellner, Schweizer-Ries & Wemheuer 2008). In 2011, new investments in renewables exceeded those in conventional energy technologies for the first time in modern history. U.S. wind power capacity almost tripled and solar energy jumped nine-fold since 2007. And 17.1 percent of Germany's electricity comes from renewable sources (DOE 2012). Therefore, environmental research which does not question physical and human factors simultaneously may reiterate environmental orthodoxies, while at the same time identification of environmental problems needs to be democratized at several levels (Batterbury, Forsyth & Thomson 1997).

### **3.6 Populous Burst**

The United Nations (UN) recently released population projections based on data until 2012 and a Bayesian probabilistic methodology has revealed that the world population is unlikely to stop growing this century. There is an 80% probability that world population, now 7.2 billion people, will increase to between 9.6 billion and 12.3 billion by the end of the 21st century (Gerland 2014). Most of the human family is still materially deprived, consuming less than its just share of economic output. This has led to renewed recognition—at least in progressive circles—that policy measures explicitly designed to spread the benefits of economic prosperity are more effective than increasing gross domestic product for alleviating material poverty (Saez 2009). Strategic distribution of resources is a widely debated subject due to different perspectives of policy makers, players in political arena, global investment priorities and current state of the planet (Figure 3). For instance, Phoenix, robotic spacecraft that was launched to Mars to search for water traces cost more than US \$386 million (Webster, Beasley & Lori 2005).

On the other side, according to the World Health Organization (WHO), investment in safe water drinking and sanitation contributes to economic growth, hence, for each one dollar invested the WHO estimates \$3 - \$34 returns (Hutton & Haller 2004), depending on technology in the region (Author leaves the math to the reader). Consequently, the complexity of the issue is displayed as a comparison of two initially unrelated evidences and may in theory provide a course for further discussion.

**Figure 3: Planetary Boundaries**



Source: Naturecom, 2015

### 3.7 Global Information Network

For effective policy procurement, the importance of social information networks, data accessibility, publicly attractive representation of the raised problem as well as convenience to actively participate for the stakeholders should not be diminished. While mobilization often starts locally and retains local roots, in this Age of the Internet it increasingly links participants in many local sites into global movements (Leonard 2010). Faster communication opportunities open horizons for more sophisticated interaction among different ministries, NGO's, business structures and third party institutions as well as assist in building international multi-dimensional networks. If it is networks that now steer politics and policy, then sustainability strategies need to first understand how they operate and then identify and build alternative networks to further support political decisions (Rhodes 1997).

### 3.8 Distinctive Technology Craft

Technology advancement and especially its manufacturing portion are sensitive subjects considering various production processes, applicability, serving-time and technical waste problem. Simultaneously, information technology, nano-technology, and molecular science are accelerating with unknown potentials, while the speed of connectivity and the interactions of globalization create complex new dynamics across sectors, areas, and societies in yet unknown ways (Galaz & Moberg 2011). The core technology for securing

the basic needs for clean water and sanitation, renewable energy systems as well as essential agriculture and cropping solutions already exist on the global market, however, the universal issue of how to utilize international cooperation among governments and businesses to make it accessible to the third world still remains unsolved. Furthermore, while extensive research is being directed to find, produce and utilize alternative fuels (for example. jet biofuels), from the point of view of environmental sustainability such rationale is even more contradicting since every hectare to harvest biofuels has alternative cost of at least one hectare of “spent” forest, lake, crops etc.

### **3.9 Environmental Business Model**

Through the history of any political ideology, developed governing structures eventually resulted in a system that from the beginning was condemned to collapse. Rather the same happens in economic systems: while the wild capitalistic philosophy is considered to be the superlative base ground for the majority of business schemes today, the artificial formula of supply – demand based on population growth and unlimited planetary resources in numerous ways is contradictory to the natural coexistence of people with the environment. Nevertheless, the concepts of the consumerism and its tools for successful implementation, if adjusted accordingly, may benefit in boosting the response and overall participation of the actors in environmental policy enforcement. Commonly, types of economic instruments employed for environmental purposes are classified into charges/taxes (emission, product, user, sanction), deposit-refund schemes, market creations, subsidies and liability schemes (Andersen & Sprenger 2000). In theory, properly designed and implemented market-based instruments allow pollution to be reduced to any desired level at the lowest possible cost to society. Incentives to reduce the greatest amounts of pollution are provided to the firms that can achieve those reductions most cheaply (Portney & Stavins 2000).

As mentioned previously, transforming sustainable environment practices into competitive market products and applying business concepts of marketing and consumerism with attractiveness and convenience of that product may be the first step in fueling the transformation in public behavior. The ability to purchase tangible or intangible goods, products and services in physical store or online should not exclude environmental products as well as acquisition of investment stocks and bonds may also include financial participation in already existing environmental programs.

### 3.10 Bridging

At this stage the attempt to closely link thousands of policy making bodies with even larger amount of researches being conducted every year on global scale may seem to be quite impracticable, considering number of such influence factors as social, demographic, technological, environmental, political, legal, ethics and religion. Nevertheless, as many other cultural, social and linguistic barriers, successful merging of two “worlds” may be achieved through professional communication and specialized interpretation processes (also mentioned previously as knowledge brokers), or in other words – consulting agencies. Such agencies, while initially operating independently, are capable to effectively search, adapt, rationalize and further implement sophisticated academic achievements primarily to the governments, public and participating businesses by utilizing not only acquired research data, but also applying market based instruments and competitive market tools to the local and global markets. Finally, the balance and risk management between three key factors of time, cost and quality should also be closely monitored with transparency.

### 3.11 Conclusion

Undoubtedly, a series of research studies have to be conducted before an effective interdependence between global-market and re-evaluated and accordingly appraised environment can be achieved. Still, marketization of partially sustainable environmental policies already exists in renewable energy production, agriculture, forestation and fisheries. Using resources sustainably is resilient. And resilience is, for the most part, sustainable: many resilient systems, such as decentralized, renewable energy and local food, would also enable us to live more lightly on Earth (Cascio 2009). We need to focus on adapting to a dramatically changing climate and environment while simultaneously pressing ever harder to head off further change. If we fail to constrain the ways we are changing the planet, the planet will eventually overwhelm all our efforts to adapt (Wapner 2010).

## Chapter 4

### Field Research: Light Aviation Segment in Japan

#### 4.1 Literature Review

The subject of renewable energy application in civil aviation has only been briefly mentioned in a limited number of available scientific articles. The environmental issues such as noise, emissions and fuel burn (consumption), for both airplane and airport operations, have become important for energy and environmental sustainability (Agarwal 2010). Few resources mentioned below raise the awareness of near future fuel scarcity issue and trend for aviation companies to concentrate on improving the efficiency of the fuel and, make a gradual transition towards bio-fuel as a renewable energy alternative. Some authors look further and introduce the concept of completely electric aircraft through electrolysis-based H<sub>2</sub> fuel chain process and powered by onshore renewable energy farms (wind, solar, geothermal, hydro and biomass). Furthermore, the MEA concept (More Electric Aircraft) that has been recently developed and heavily sponsored by few aircraft electronic and instrument manufacturers suggest a new insight and technological solutions for general improvement of aircraft performance by utilizing electric power on all non-propulsive systems.

Nevertheless, while technological progressive systems permit to improve the efficiency on different aspects of aviation industry, the chase to beat the escalating fuel costs (that remains to be the principal dependence factor) might soon reach the breaking point of global supply - demand equilibrium. With the highly potential burnable fuel energy crisis together with under-balanced global consumption rates, aviation industry is a primary target to yet another energy emergency due to extreme dependency and volatility on high-graded aviation fuel. According to the industry experts (as quoted from DiGeorgia 2014):

*“Airlines, along with airframe and engine manufacturers, have made enormous strides regarding efficiency, but the industry still runs on oil; It makes environmental and economic sense to reduce dependency on this one commodity, and whoever can develop a viable alternative will have a lot of eager customers.”*

The work of Saynor, Bauen and Leach (2003) was found to be most comprehensive in

terms of detailed evaluation and implication of various types of fuel types and renewable energy resource options in aviation industry. By using quantitative analysis approach the authors describe potential application of biodiesel, ethanol, methanol, Fischer - Tropsch synthetic kerosene, nuclear, liquefied hydrogen ( $H_2$ ) and liquefied bio methane and further investigate whether they are potentially favorable. Some of the options such as methanol, ethanol and bio-methane were rejected at the early stage due to low ignition points, toxicity and quality issues, while nuclear aircraft raise too many national security and overall safety questions.

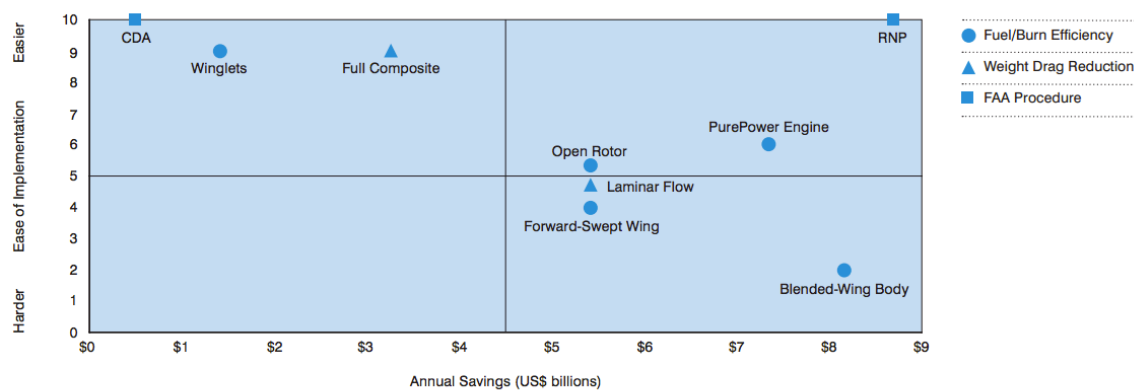
Synthetic Fischer - Tropsch kerosene produced from biomass, biodiesel and liquefied  $H_2$  were considered in detail as a potential alternative as a renewable fuel. Particularly in the case of hydrogen that is generated from offshore wind electricity farms,  $H_2$  has been considered as a fuel option in Europe, US and Russia from the early 1950s. However, while being produced in environmentally sustainable way,  $H_2$  fuel requires complete reconstruction of the aircraft's airframe and fuel tanks, raises the issue of oxides of nitrogen ( $NO_x$  - especially as atmospheric pollutant) and is highly volatile to public's resistance regarding safety of  $H_2$  in general.

To further back up the theory, the field-research conducted within Japanese small aircraft/rotorcraft operators has revealed numerous responders that stated diesel to be the next choice for aviation industry as cheaper and more reasonable preference. While diesel engines still suffer some altitude limitations, few small aircraft manufacturers have already tested and launched into production single and multi-engine turbo-charged piston engine powered aircrafts (for example Cessna 182, Cirrus 22s, Diamond 42 for general aviation purposes). Nevertheless, for the purpose of the study neither the diesel/biodiesel nor synthetic kerosene may be considered as a renewable resource due to production from highly expensive biomass in former and mixture with conventional kerosene in latter.

Kronenberg and White (2008) argue that due to escalation of the jet fuel prices from historical 10% - 15% to recent 40%, airlines have no choice but invest in fuel-efficient technologies and support alternative energy resources as a first step to ease the dependence from the oil-based fuel. The authors signify the importance to concentrate on gradual equipment upgrade that influence fuel consumption, route optimization as well as early transition to alternative fuel sources and re-structure of existing business models as the key ways to achieve more sustainable and lower emission future for the airlines.

It is important to notice that especially in the aviation industry any technological method that improves the performance of the aircraft and at the same time decreases the costs of its operation is directly attributed to the green factor rating since the aircraft becomes faster, consumes less fuel, may carry heavier loads, hence, is environmentally cleaner within its type and size. By measuring various implementation methods against value of cost savings, one might observe potential upgrade options that directly affect the fuel consumption rate and operation costs (Figure 4):

**Figure 4. Matrix of savings vs. ease of implementation\***



Source: Booz & Company

#### Definitions:

CDA – *Continuous Descent Approach*

Winglets – *a vertical projection of the tip of the aircraft wing to reduce drag*

Full Composite – *aircraft structures made of fiberglass, carbon fiber or fiber-reinforced matrix systems*

RNP – *Required Navigation Performance*

Laminar Flow – *smooth, uninterrupted flow of air over the contour of the wing*

The researchers from Boeing, Airbus, the FAA, Air France and KLM at the Green Aviation Management Forum that took place in Madrid in September 2008 concluded that next fuel sustainability choice has to meet following criteria:

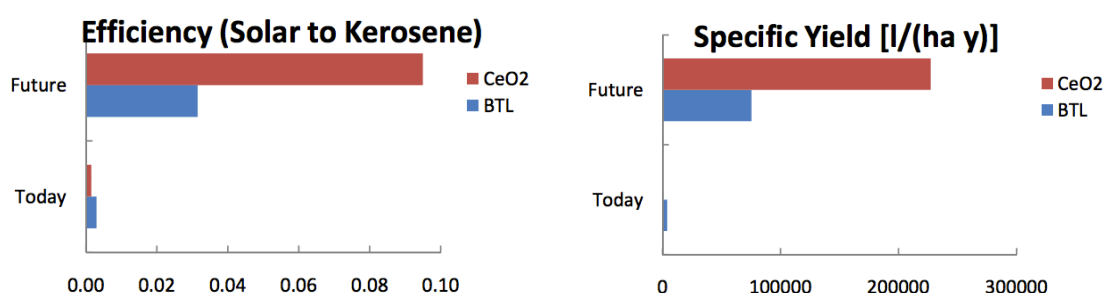
- It has to be scalable, cannot be feed stock and must have a stable supply;
- It has to work with existing jet-fuel infrastructure and meet performance standards;
- It must be cost efficient, not to cause net-harm to the environment and be long-term economically proven.



The conference findings revealed that within three alternative resource development methods, such as coal to liquid (CTL), gas to liquid (GTL), and biomass to liquid (BTL), only the last one has the actual economic potential to be used in aviation industry (Figure 5). Based on approximate calculations, algae-based jet fuel would cost in a range of 70\$ - 80\$ per barrel, that could bring back aviation industry to more favorable economic environment and postpone energy crisis. According to Lundquist (2010), renewable algae oil could be a major contributor to biofuel resources, particularly in specific markets, such as aviation fuel.

However, in just three years period Dr. Sizmann (2011) at ICAO (International Civil Aviation Organization) Aviation and Sustainable Alternative Fuels workshop with his associates have argued the efficiency and sustainability of biomass as a direct environmental impact on ecosystems of inland water bodies, forest areas, constrained habitats conservation zones and settlement areas. As a contra-solution three new concepts were introduced: sunlight to liquid (STL), solar thermo-chemical reactor, and an all-electric power system that is zero-emission, and flexible in choice of primary energy. Therefore, electrical energy can be generated from solar radiation, accumulated in batteries and through highly efficient motor technology directly transferred to motive power. Sizmann also proposed that efficiency of electric energy carriers is more than three times when compared to hydro-carbon fuels due to lower system barriers and extremely high exergy (usable energy) density (Figure 5). In addition, CO<sub>2</sub> itself becomes a resource, not the undesired emission. (While the automotive industry has already stepped into early stages of zero-emission vehicle mass production, a few pioneers such as Bye Aerospace, Pipistrel and Chip Yates have managed to successfully test and fly all-electrical powered small aircraft).

**Figure 5. Theoretical Potential of STL to BTL**



Moreover, technological advancement in photovoltaic solar panels as well as geometrical

progression in battery accumulation capacities achieved by Nissan Motors in Japan and Tesla Motors in the US moves the efficiency gap even further between BTL and CeO<sub>2</sub> (ceria – redox materials that display rapid fuel-production kinetics and high sensitivity, Robinson 2013). Therefore, while it is still a long shot to assume jet engines will be powered by electricity in the next decade, the small aviation industry has already made a breakthrough in technology and innovation that serves as a base to further develop and research the methods to implement renewable energy concepts toward zero-emission environmentally sustainable small aviation operations.

## **4.2 Interview Background and Findings**

This field research on the light aviation industry in Japan was conducted from July 10 to July 20, 2014 in Tokyo and Osaka prefectures, as the largest congested areas and company locations in the country. Numerous questions were raised during the interview sessions with company managers and chief pilots, and static data was collected about the company, its financial performance and overall operation procedures (see complete questionnaire in Appendix B). However, there was a serious lack of information available regarding primary subjects of sustainable operations, environmental impact tracking or the renewable energy concept. Therefore, for the purpose of the research, data collected from the interviewers was analyzed from the perspective of the whole industry, with the exception of the segments that stand out of the general pattern.

### **4.2.1 Company overview, operational procedures and target customer**

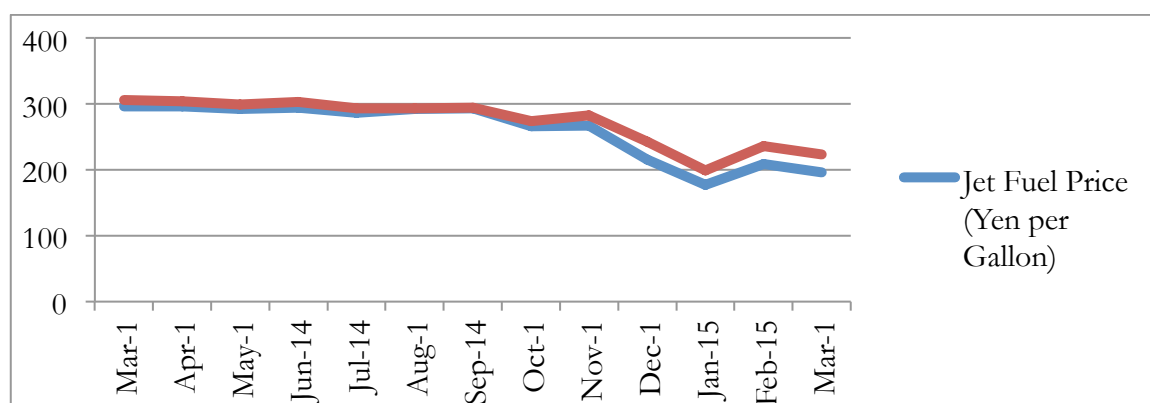
The types of business activities of the companies are divided in seven sectors: business charter operations, pilot-student training, scenic flights, aviation clubs, aerial photography (also mapping services), news coverage and medical services (helicopters). Some of the companies are also participating and emergency response programs, where location and proficiency permits. Due to the nature of on-demand business operations, some diversification may be seen in scenic flight, aerial photography and aviation clubs, since such companies are more flexible on providing broader range of services depending on customer's preferences. Since every aircraft/rotorcraft operator in Japan must comply with the laws established by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), there are no visible exceptions in terms of following standard operational procedures regardless type of business.

#### 4.2.2 Cost structure, resource supply, direct operational cost, governmental subsidies

In the cost structure and resource supply section, while numbers fluctuated depending on type of flight operator, the most critical part of all direct operational costs consisted of fuel expenses and maintenance (especially in Japan, with one of the highest salary rates in aviation industry sector within the whole Asia: according to CareerCross.com median for aviation technician/maintenance mechanic/aeronautical engineer yearly salary ranges in between 4 million~6 million Yen/per annum). Field research study revealed that fuel consumption varied from **35% to 45% of total operational costs** (Figure 6 and Table 1). From the bigger picture, even though there was a recent drop in crude oil prices globally, the temporary change did little influence on flight operators due to the policy of having fixed price contracts with the suppliers, and from the perspective of the passengers/air - service customers there was nearly no noticeable (or even equivalent) drop in hourly or ticket prices (Nytimes.com 2015):

*“A recovering economy and rapidly falling oil prices have provided some breathing room for airlines in recent months, bolstering profits and allowing carriers to buy new planes or upgrade their higher-end service. While motorists have seen gasoline prices fall at the pump, air travelers should not expect to see fares, or even fuel surcharges, drop anytime soon. Airlines were quick to slap extra fuel charges on their international flights when oil prices spiked a few years ago. Today, those can reach about \$500 for a round-trip international flight, for instance, between Newark and Frankfurt, or Los Angeles and Tokyo. But with oil prices down more than 40 percent since June, airlines have been a lot slower in cutting back those surcharges, particularly at a time when they have no trouble filling planes at current fares. Fuel accounts for nearly half an airline’s costs. But airline executives are unsure where oil prices will settle or how sustained the downturn in the oil market will be. Alexandre de Juniac, the chairman of Air France-KLM, estimated that oil might hover between \$70 and \$80 a barrel next year, although he added, “Obviously, no one really knows.”*

When responders were asked about how they see the future development of the small aviation in terms of finding alternative energy resources and cutting off crucial dependency on crude oil prices, 35% of the flight operators mentioned possibly transferring to diesel engine sometime within the next five to ten years, while the other 65% did not express any potential vectors for future solutions.

**Figure 6. Jet Fuel versus Diesel - Price Rate of Change Comparison**

Another important cost factor mentioned were the existing Japanese government oil purchase agreements (as a natural resource) with other trading countries. Japan's bonded jet fuel sales totaled 7.4 million kiloliters in fiscal 2012, up 3.4 percent from a year earlier, according to data compiled by the Petroleum Association of Japan. That's about 127,000 barrels a day: "JX Nippon Oil & Energy Corp. and Idemitsu Kosan Co. will shut refineries next year amid closures that have reduced Japan's processing capacity by 27 percent in the past thirty years. That's driving up the cost of domestic jet fuel and prompting airlines to look further afield for supplies" (Bloomberg.com 2015).

**Table 1. Jet Fuel versus Diesel - Price Rate of Change Comparison**

Month	Jet Fuel Price (Yen per Gallon)	Diesel Price (Yen per Gallon)	Jet Fuel ROC	Diesel ROC	Jet Fuel / Diesel Price Ratio
Mar-14	295.57	306.1	-	-	0.9656
Apr-14	296.2	303.38	0.22%	-0.89%	0.9763
May-14	291.91	298.93	-1.45%	-1.47%	0.9765
Jun-14	294.22	302.28	0.79%	1.12%	0.9733
Jul-14	286.51	292.82	-2.62%	-3.13%	0.9785
Aug-14	292.3	293.43	2.02%	0.21%	0.9961
Sep-14	292.67	293.85	0.13%	0.14%	0.996
Oct-14	265.83	273.72	-9.17%	-6.85%	0.9712
Nov-14	266.49	282.04	0.25%	3.04%	0.9449
Dec-14	214.88	242.68	-19.37%	-13.95%	0.8854
Jan-15	176.99	198.52	-17.63%	-18.20%	0.8915
Feb-15	208.08	236.06	17.57%	18.91%	0.8815
Mar-15	196.11	223.44	-5.75%	-5.35%	0.8777

*\*Source: Independent Statistics and Analysis: US Energy Information Administration: Petroleum and other Liquids*

#### **4.2.3 Geographical positioning, main competitors, agreements with business and government organizations**

For specific type of operations such as news coverage and scheduled charter services (as well as emergency response functions), geographical positioning usually plays a critical role in reaching out target locations within shortest period of time and also directly impacts time of travel for the customer to arrive to initial point of departure. However, due to the considerable operation limitations in congested airspaces, majority of small and medium operators choose to locate their headquarters further away from metropolitan areas to avoid substantial waiting periods with the controlled airspaces and also benefit to the overall noise reduction in the designated area.

As for the pilot training facilities, which represent nearly 50% of the all questioned responders, being positioned further away works in favor due to already mentioned traffic congestion and ambient noise issues, while being considered as higher risk operation, remote location also benefits to the overall safety in case of theoretically higher percentage of potential cases of emergency. While competing within local market, Japanese small aircraft / rotorcraft operators do not face any visible competition from overseas companies, therefore, by being privately owned, in current market conditions Japanese companies lay in a lower portion of supply / demand equilibrium, hence, competition levels are not significant and did not raise threats for future survivability at the time when this research was conducted. While healthy competition does exist in the market, due to the highly complicated governmental requirements and regulations, the market penetration by small aircraft/rotorcraft foreign operator is nearly non-existent (except of aircraft private owners with occasional provision of charter service), while local companies are still far away from satisfying national demand, especially when attempting to deal with snowballing pilot shortage both in Japan and Asian Region in general. According to Japan Times: “Last year, Boeing estimated that, between 2014 and 2033, the Asia-Pacific region will need 216,000 new pilots. But according to a 2011 study from the International Civil Aviation Organization (ICAO), the United Nation’s aviation agency, the region is only capable of training 5,000 pilots per year. For anyone who can’t earn a spot in a local flight school (many of which are government-run or affiliated), the only option is to apply to one outside the region” (Japantimes.co.jp, 2015). Especially in Japan, where pilot training is the most expensive in the world costing more than three times compared to the global standard commercial pilot license course, such dramatic pilot shortage situation clearly indicates that

while Japanese operators feel some competition within the country's boundaries, the potential market growth trajectory is still at its early stages of development for extensive scale up.

Nevertheless, from the point of view of national economy, aviation industry in Japan plays a significant role in terms of GDP structure. According to Oxford Economics Study: "aviation has a significant footprint in the Japanese economy, supporting 0.7% of GDP (JPY 3.135 trillion) and 0.7% of the Japanese workforce (429,000 jobs). Including aviation's contribution to tourism, the figures rise to 1.0% of GDP (JPY 4.501 trillion) and 1.0% of the workforce (620,000 jobs)" (IATA). Consequently, since pilot training facilities occupy large portion of small aircraft/rotorcraft operators and in turn position themselves as an initial key element for supplying future pilots for the industry, strategic future development vector of such companies is critical and has to be addressed in detail on governmental level. While the Japan Civil Aviation Bureau states itself working in close proximity with International Civil Aviation Organization (ICAO) and International Aviation Transport Association (IATA) established standards and regulations, in practice such standards are considered as informative guidelines for reference purposes only, and national regulations remain to be unarguable set of laws and statutes if any official procedure, documentation or certification is to be placed for approval.

#### **4.2.4 Safety procedures and requirements, Federal Aviation Regulations**

Ministry of Land, Infrastructure and Transport being the top governing body in establishing safety regulations is a final decision maker for administrative policy structuring and implementation. The Civil Aviation Bureau issues circulars for aircraft safety to provide the policy, standards, guidance and other information related to JCAB activities such as certification of aircraft, approval of maintenance organization and approval of the air-carrier's maintenance program (Mlit.go.jp, 2015). The list of classified circulars:

- 1) Procedure and Policy concerning Certification / Approval for Aircraft / Parts
- 2) Procedure and Policy concerning Approval Organization
- 3) Procedure and Policy concerning Maintenance
- 4) Procedure and Policy concerning Air Carrier
- 5) Procedure and Policy concerning Operation Approval
- 6) Other Policies

Field research has revealed that safety standards remain extremely high and every operator strictly complies with the established safety procedures and regulations. When asked, responders confirmed that even a small misconduct is treated seriously with attention to document each detail and is followed with relevant statement reports to avoid any repetition in the future. The general philosophy states that there is never too much safety in the industry that by default has high-risk levels during different sections of operation. Failure to comply with the regulations almost always lead to loss of applicable certifications and permissions with complicated, timely and cost-consuming processes of reinstatement.

Federal aviation regulations are standardized to fairly comparable levels of ICAO circulars that include charts, radio communication language (English) and procedures, instrument and visual flight rules, airspace separation regulations as well as general navigation procedures with some minor exceptions relevant to Japan specific regional requirement. In fact, due to recently common practice to conduct initial training of Japanese pilots overseas (gaining approximately 80% of flying hours in United States due to substantially cheaper fuel and cost of operations), training manuals in such Japanese training facilities have a close resemblance to US Federal Aviation Authority guidebooks and educational materials.

#### **4.2.5 Airway availability and congestion of the airspace**

Since the majority of operators are located within the hub of a metropolitan area, airspace congestion is a growing issue, especially considering the fact that medium and large air transport operators have a pre-assigned priority for airway usage and time slot allocation for takeoff and landing at large airports. In fact, small aircraft / rotorcraft companies tend to avoid operating in the proximity of large airport terminal due to air traffic congestion and, of course, slower operating speeds. Nevertheless, the geographic distribution of major airports in Japan suggests that marginal portions of airspaces are controlled and inevitably it will be necessary to share the airspace with the strictly imposed regulations, and this will not work in favor of smaller operators.

According to the latest Air Navigation Report of ICAO (Icaoint 2015) on Capacity and Efficiency, some 3.1 billion passengers made use of the global air transport network for their business and tourism needs in 2013. The annual passenger total was up approximately 5% compared to 2012 and is expected to reach over 6.4 billion by 2030, based on current projections. The number of aircraft departures reached 33 million globally last year,

establishing a new record and surpassing the 2012 departure figure by more than one million flights. Scheduled passenger traffic grew at a rate of 5.2% (expressed in terms of revenue passenger-kilometers or RPKs). The Asia-Pacific Region remains the world's largest air transport market based on the 2013 figures, with a 31% share of total traffic representing an increase of 7.2% over 2012.

Few responders in Tokyo and Osaka areas has confirmed that it has become usual to fly on average 20 minutes one way to reach the approved training air zone where safe separation from active air transport traffic may be secured, together with acceptable noise amendment requirements and safe landing areas in rare cases of emergencies.

#### **4.2.6 Track of environmental impact**

At the time of the field study, tracking of environmental impact was addressed from two perspectives: first, whether there are any environmental practices (such as CO<sub>2</sub> reduction, application of renewable energy system in any part of operational process, use of eco-friendly materials, implemented company policies to reduce, preserve, optimize energy usage and any other environmental practice) being conducted presently, and if yes, when, why and how it was started. The second part of the question was oriented towards initiative to apply any of the mentioned practices in the future, and if yes, which ones specifically, at what extend and during what period of time.

To my sheer surprise, except for two pilot training facilities that practiced turning-off air conditioners with the permission to loosen jackets in an office during summer time, as well as the proper utilization of used engine oil by delivering it to suitable recycling factories, there was no visible environmental concept applied so far. However, an important note has to be highlighted regarding the general operational philosophy of small aircraft / rotorcraft operators in Japan: while there were no traceable environmental practices, the overall operations of Japanese aviation companies hold one of the top global ranks in terms of industry safety, high-end quality system maintenance, extreme attention to details and proficiency of training and continuous raising of qualifications for human resources.

Only one company expressed a distant possibility to place number of solar panels on the roof of a hangar to achieve some potential cuts on electricity usage. Nevertheless, this project is to be considered only in the future and only under the condition of exceeding



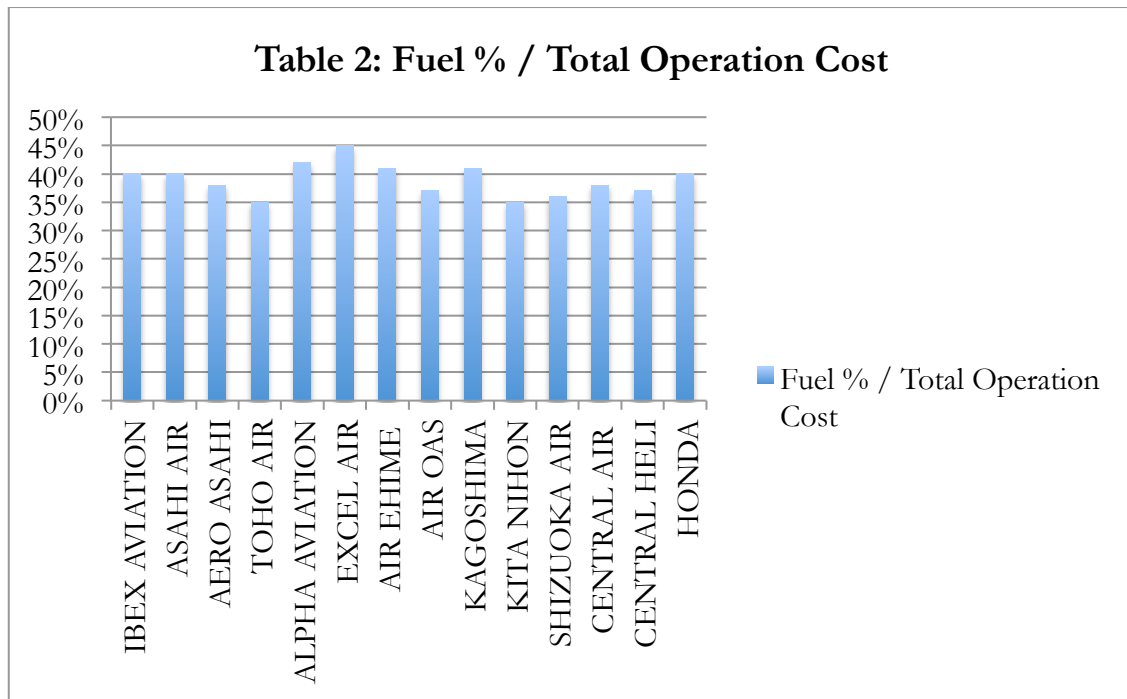
company's financial expectations, since regardless the forthcoming benefits of installing solar batteries, requirement for substantial initial investments and continuous maintenance costs, such step towards environmental sustainability is far off from first company financial priorities. Finally, the total price of a kilowatt generated from one square meter of the solar panel is still not competitive, compared to buying the same kilowatt from the grid.

### 4.3 Collected Data Analysis and Results

Data collected during field research has revealed three critical issues within the small aviation industry in Japan:

- a) Aviation fuel on average contributes to 38.93% of total operational costs of small aircraft / rotorcraft Japanese operators (see Table 2: Fuel %/Total Operational Cost) and remains to be a critical dependence factor in service cost structure. In addition, even considering current (2015) lower global crude oil prices, there is no evidence in permanence of the price stability; and, in combination with Japan's petroleum import tax system (see Table 3) no visible and/or practically applicable alternatives for aviation fuel is being studied by small operators at this moment (transfer to diesel engine is not considered as an alternative due to insignificant price different between high grade aviation fuel and diesel).
- b) There are close to zero of conducted practices that can be related to sustainable or environmentally friendly operations. There are also no clear vector of such developments in the future being considered by the operators that at the same time raises concerns about how environmental issues are being addressed by the industry.
- c) Considering alarming condition of future pilot shortages and highly possible expansion of flight training operators nationwide to attempt meeting exponentially growing demand, no fuel alternatives are being introduced or otherwise studied that may be applied to the small aviation industry sector to help meeting environmental sustainability initiatives applicable for transport sector:
  - Smart consumption of energy by using energy management
  - Promotion of the use and diffusion of vehicles with lower environmental load

- Promotion of traffic flow management and promotion of the environmentally-friendly usages of vehicles
- Promotion of low-carbonized transportation through railway, vessel, and aviation
- Power from renewable energy sources (env.go.jp, 2015).



#### 4.4 Further Research

To further back up the study, an investigative research has to be done on all aspects of small aircraft/rotorcraft production chain phases to understand the potential of sustainable alternatives that can be applied in this industry sector. Therefore, the detailed examination of aircraft with electric propulsion, electric and solar aircraft, high-performance Li-ion and Si-based batteries, autonomous flying, carbon-fiber airframe and propeller, hybrid systems and other relative innovations currently available on the global market have to be closely studied.

#### 4.5 Conclusion

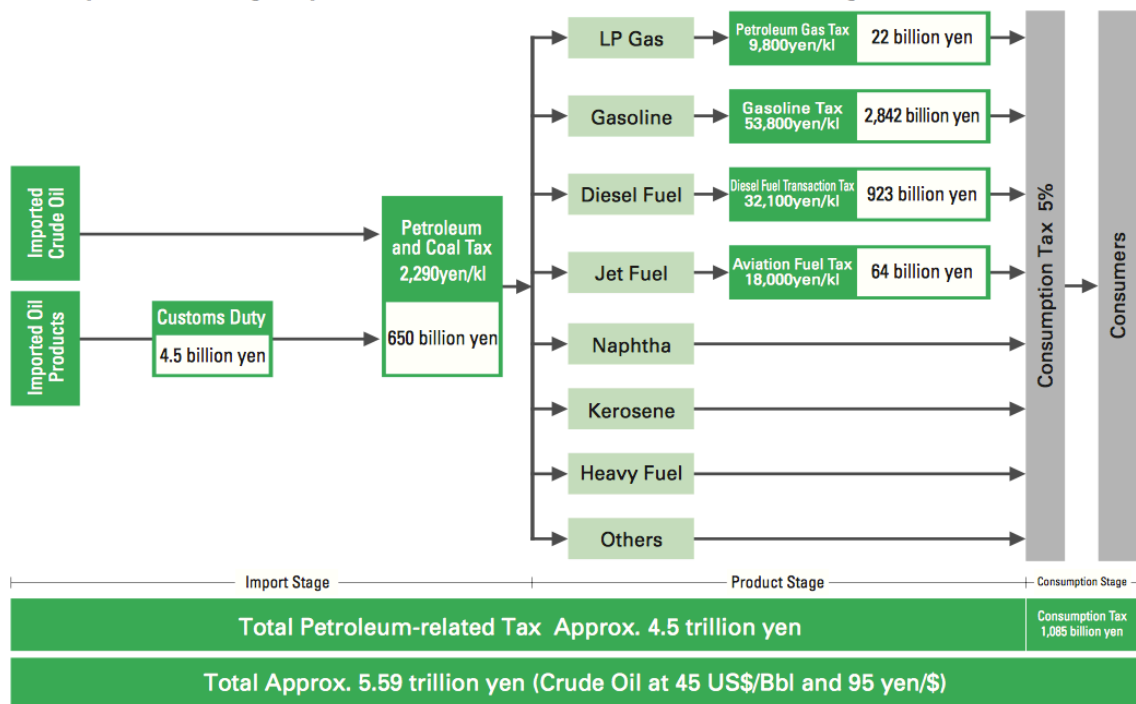
The field study of small aircraft/rotorcraft operators in Japan has highlighted three fundamental issues and provided detailed insight into actual situation and current state of small aviation industry. While Japanese companies remain to lead the way for safety standards and quality of technical maintenance, environmental practices and sustainable

operation are barely noticeable. Furthermore, with the growing demand for pilot training facilities, current local market state is not capable to provide a scalable solution for an existing and snowballing issue. Environmentally sustainable operations are not practiced and no substantial evidence has been found that there are trends for a change within the nearest decade.

The following chapter will provide detailed research regarding technological breakthrough in small aviation industry currently available on the global market from high performance Li-ion batteries to electric propulsion aircraft powered by renewable energy systems. Therefore, by considering various aspects of safety, performance, applicability, regulations, scalability, transition issues and licensing procedures an analytical framework can be structured to answer the initial research question of implementing renewable energy concept into small aviation operators in Japan.

**Table 3.**

■ Multiple & Multi-stage Imposition of Petroleum-related Taxes (FY2013 Budget)



\*Source: *Petroleum Industry of Japan* (Pajgr.jp, 2015).

## Chapter 5

### Field Research 2: Electric Aircraft Symposium (IX) 2015, California, USA

#### 5.1 Introduction

This chapter presents a small aviation industry analysis through investigation of industry's technological innovation processes, based on four main elements in the diffusion of innovation theory, which are:

- 1) The innovation – which technological achievements in small aviation industry are being adopted in the early stages.
- 2) Communication channels – how new innovation is displayed to the end user.
- 3) Time – how well timed is the innovation and what rate of adoption may be expected.
- 4) The social system – how the diffusion of innovation affects both small and general aviation industry's mass end-users.

The analysis of five cases provide an industry insight as well as assist answering research question:

What practical applications of renewable energy concept in aviation industry currently exist (industry analysis from global perspective)? The findings reveal small aviation industry existing challenges, financial implications, success factors and provide critical constraint analysis.

#### 5.2 Regenerative Electric Flight

*(J. Philip Barnes, Northrop – Grumman)*

Electric-powered flight is coming soon in a big way, with battery specific energy poised for dramatic gains. A key aspect of electric flight will include a "regeneration" feature whereby, when the aircraft encounters an updraft or descends, the propeller serves as an airborne wind turbine to regenerate energy stored in the battery (or other energy-storage unit). The 2006 SAE paper "Flight Without Fuel..." was first to show the feasibility of the regenerative electric flight concept originated by Paul MacCready. Concept of dynamic soaring is originally based on length of flight on energy regeneration process by comparing possibility to design electric powered aircraft by learning from one of the most natural gliders –

albatross. The key principles that make the albatross a professional in utilizing wind efficiently and preserve energy for long periods of time are:

- a) Airspeed determines the flight, while groundspeed is not considered relevant to overall flight efficiency;
- b) Utilization of gradient of the wind (another key component) - albatross is cutting off energy as low as 5-10 meters over the sea;
- c) Bird's sensor platform remains at level, even at the 90 degrees bank;
- d) Unique ability to be able to fly up-wing by staying close to the water;
- e) From the point of view of net progress – the bird is capable to fly almost effortless to any direction without flapping;
- f) Use of thermals: Albatross is experiencing 3G load every 12 seconds.

Now, while some of the mentioned functions are not directly applicable to an airplane flight, a few key elements are found to be effective and feasible when combined with current technology. For either the sailplane or “clean” energy regeneration, sink or climb performance is degraded as load factor is increased, with Lift to Drag (L/D) ratio evaluated at the lift coefficient under load. Thus, turning “twice increases” the drag penalty, and this calls for high aspect ratio (learning from the albatross and frigate bird!) to mitigate this effect. Should we choose to incorporate the regeneration feature into our electric aircraft, several useful capabilities become by-products. Aside from the benefit of regeneration in flight, we can steepen final descent, apply reverse thrust during the landing roll, and recharge pointed upwind on the ground. Then, another perspective is a utilization of the thermal waves where equilibrium regeneration can be achieved when applied in wave lift, ridge lift, or descent.

To attain a regenerative electric flight, the principles of a motor-generator are found to be highly synergetic and efficient in the wind prop and brushed motor generator. For an energy regenerating aircraft high L/D, low wing loading, and high component efficiency can together enable total energy gain during regeneration.

Finally, by enhancing range, steepening descent, providing landing-roll thrust reversal, and enabling recharge with the aircraft parked on the field facing upwind, (of course, depending on weather and geography), a regenerative flight has the potential for “flight without fuel.”

### 5.3 Low Aspect Ratio Electric Aircraft

*(Barnaby Wainfan, Northrop Grumman)*

While we mostly see low aspect ratio airframe designs in military aviation, by making 21 aircraft designs fly with an average of 4.5 aspect ratios, Mr. Wainfan's work provides yet another important insight into new energy efficient aircraft concepts.

Why do low aspect ratios work? Whereas low aspect wing aircrafts require trading aerodynamic efficiency to structural efficiency, such airframes allow achieving up to 40 degrees angle of attack. For example, FMX-5 being a perfectly flying aircraft has aspect ratio of only 1.5, (which is lower than military aircraft powered with a jet engine where thrust exceeds weight). In general, L/D depends on wing-span, span efficiency, skin friction drag and wetted area, the low aspect aircrafts represent completely different approach where actual ratio is payload to drag, but not L/D. Hence, in terms of commercial transport efficiency, the benefits of payload "travel" from point A to point B becomes more apparent.

Furthermore, by introducing electric propulsion possibilities into such type of aircraft, distributed propulsion can be achieved, where high ratio is at flight peak and cruise (while propellers rotate outward). In addition, it also increases span efficiency. Finally, electric propulsion systems with electric driven tip propeller are much easier to implement on low aspect ratio aircraft, and more importantly, makes the overall transition to electric propulsion being lighter in weight.

### 5.4 E-Fan, The Way Forward

*(Ken McKenzie, Deputy Chairman, Airbus Group)*

Airbus, being one of the leading aviation industry manufacturers in the world in the aircraft, helicopter and military sectors has presented a working model of electric aircraft E-Fan, probably the most advanced prototype currently available in the market. Without a doubt, powered by gigantic infrastructure, decades of experience in aviation technology and innovation as well as unarguable human and capital resources, Airbus group just once again established itself as a primary market leader in making and industrializing its products - regardless of weight, size or type of propulsion. While Boeing remains a size competitor in theory and in practice capable of delivering an equally potential electric aircraft version of its own, the author does not consider Boeing at this stage, since their vision of future

electric propulsion in the aircraft does not mention such development in the small aviation sector.

As stated by Airbus, the primary reason for placing the company's attention on electric aircraft is the desire to meet with European Commission's (EC) desire path 2050, and hence, make a substantial positive influence in terms of CO<sub>2</sub> emission reduction project. The overall targets for aviation set by EC are to reduce CO<sub>2</sub> by 75%, nitrogen oxide by 90% and noise levels by 75% all compared to year 2000.

The Airbus E-Fan exhibited at Farnborough (Economist.com, 2015) is built largely of lightweight composite materials. A series of lithium-ion batteries, similar to those used in electric cars, are housed in sections of its 9.5-meter wings. The electric motors drive a pair of ducted fans mounted on either side of the rear fuselage. The key benefits of eFan:

- 1) Efficiency – equipped with 400amH (600 Kwt, 1.5 Newtons) batteries that generate 4 volts per cell, the current model is capable of achieving maximum speed of 160 knots (equivalent to the widely used fuel combustion engine of Cessna 172 trainer aircraft). It is also capable of landing with only 112 feet of runway, and a maximum takeoff roll of 220 feet.
- 2) Quiet—the demonstrated noise levels are kept below 60DB (Industrialnoisecontrol.com, 2015), which is comparable with normal conversation at the restaurant or office. Such feature also potentially allows operating aircraft in the airfields close to suburbs on the daily basis without disturbing the residents.
- 3) Clean – no direct CO<sub>2</sub> or any other toxic emissions. If the batteries are re-charged from renewable energy resources, the operation of the aircraft exponentially raises its level of environmental friendliness. However, utilization of high-capacity Li-Ion batteries (that by result of shifting to electric propulsion will directly impact battery manufacturing globally) still remains a serious issue.
- 4) Scalable – with Airbus technology on hand, once proved to satisfy both Federal Aviation Authority certification requirements and demand for sufficient range (current flight duration ranges in between 45 to 75 minutes) for the consumer, the company is confident to place various future upgraded models into mass production.

- 5) Compact – E-Fan being manufactured of entirely carbon fiber airframe has 500 kg empty weight with 650 kg of maximum takeoff weight and has 16 L/D ratio.
- 6) Reliable – initially just a two seat-model, the aircraft is armed with the latest navigation equipment while carbon fiber airframe responds to required strength and flexibility of the plane.

In conclusion, to add a sense of nature to the project, Airbus marketing strategy for E-Fan is stated to be “Clean as a butterfly, hums like a bee”.

### 5.4.1 Existing Challenges

#### a) Energy Storage

Nevertheless, even for such market leader as Airbus, aircraft driven by electric propulsion face numerous of challenges that are restricting one of the most crucial factors – range of flight with a safety reserve. Energy density that can be stored in the different modifications of Li-ion batteries is still far from the normal diesel engine in terms of weigh and cost equilibrium. (For comparison, when asked about future opportunities to apply electric aircraft concept in to larger aircraft - which in fact is Boeing’s long term strategy - based on the research done by Airbus, the following was stated: “Even if we replace jet engines with most efficient electric engines and place advanced batteries instead of fuel tanks in the middle sized jet in on average of 150 – 200 passenger capacity aircraft, we would still require to trade more than 1 ton of batteries for each passenger to travel the same range on aviation fuel”). Furthermore, the chemical structure of Li-ion batteries in large quantities cause serious safety concerns and are subject to uncontrolled inflammation, and this will be discussed further in this chapter.

Carbon Fiber material – while carbon fiber is a great innovative lightweight solution for an aircraft’s airframe, complicated maintenance issues raises considerations to turn back to a combination of aluminum (for example. batteries cowling) and carbon fiber.

#### b) Certification

At this stage timing for certification has not been specified, yet a fully certified model of E-Fan is to be presented to customers by the middle of 2017. Still, introduced “Roadmap for



E mobility” displays a determined effort to gradually transit to electric propulsion through step-by-step implementation and testing processes of new technology:

Fully Electric Experimental Aircraft => E – Star 2 Hybrid Propulsion Model => E-Fan  
 Fully Electrical Training Aircraft => Helicopter Hybrid Propulsion => E-Thrust Hybrid  
 Propulsion => Fully Electrical Helicopter => Fully Electrical Passenger Aircraft (within  
 next 20 years at least a medium size commercial aircraft).

While current concentration is placed on already utilized hybrid electric propulsion helicopter, research related E-Fan project is now a third step in Airbus E-Mobility road path.

#### **5.4.2 Electric Aircraft Models**

In addition to numerous tweaks and changes to improve aircraft’s performance, the first version of E-Fan 1.0 innovations included battery systems, electric motors, telemetry systems, e – FADEC (full authority digital engine / electronics control) and landing gear.

Further, E-Fan 2.0 project (current 2015 model, see Note 5) by utilizing latest TESLA Automobile battery technology, the upgraded model is expected to have 1.5 hours range with approximately 30 min to full charge. However, the market breaking challenge is to achieve 6 hours of flight time charge with as little as 5 min re-charge to full capacity (equivalent comparison in terms of time required to fill the fuel tank).

Since the small aviation industry largely consists of training facilities, the most efficient utilization of the aircraft is a critical factor influencing success and profitability of the company. According to Airbus research, the ideal average for plane utilization is somewhere in between 11 hours a day with approximately 30 minutes on the ground between the flights. Therefore E-Fan 4.0 – the next four seat aircraft (surprisingly, sold only for American region) will be a new hybrid model for general aviation purposes, with a range of 4.5-5 hours with the base of internal combustion engine.

#### **5.4.3 Financial implications**

The E-Fan project, as reported, with over 20 international partners has a price tag of 50 million Euros in investments, with additional 20 million Euros for a recent assembly line.

E-Fan is considered as a long-term asset without positive short-term impacts on the company's stock price.

To conclude, Airbus is looking to meet the demand for future business travellers, and the general aviation, as well as in the helicopter sector. The concepts of ducted fans, electric driven wheel combination and multiple hybrid systems are being continuously tested for potential near-future applications. Still, battery cell weight and price remain as their unknown factor (or not currently displayed for public) due to constant fluctuations and volatility of the materials in use.

### **5.5 Sunflyer, The Two-Seat Electric Trainer**

*(George Bye and Calin Gologan)*

While Airbus is perfecting electric propulsion aircraft and battery technology with the E-Fan project, from the perspective of environmental sustainability, changing the engine and type of energy capacitor does not resolve the issue of energy generation itself (since burning cheaper fuel to generate electricity results in greater energy losses at the end of the day).

SunFlyer can be called a disruptive innovator in the small aviation industry in a sense of implementing renewable energy concept at the beginning of the production line. By eliminating dependency on battery capacity, George Bye and his team have found a way to re-charge the plane in flight with renewable energy technology by designing an aircraft with solar panels. While covering wings with solar panels can also be seen in other prototypes (mostly gliders with small electric engine to extend flight range while in cruise), the SunFlyer design considers all trainer aircraft parameters that are necessary to qualify for certification requirements.

From the perspective of aviation industry trend development, More than 235,000 extra pilots are needed over the next seven years to meet global demand for air travel, according to one of the world's biggest aviation training companies (Nathalie Thomas, 2015). However, to meet this demand industry is facing serious challenges such as aged training fleet, the cost of new aircraft and training technology, and high fuel and operation costs, as well as increasing noise and exhaust concerns. By addressing the 20-year total market of pilot shortage growth and replacement of legacy (aircraft) trainers, this company present market analysis in terms of TAM (Total available market) of 82,000 trainers, SAM (serviceable available market) of 32,000 trainers, and the potential target for SunFlyer SOM (serviceable obtainable market) of 8,000 trainers. Starting from 1956, there have been more

than 74,000 models of the Cessna 150, 152 and 172 produced to date of one of the most popular and widespread trainer aircraft in majority of training facility fleets. Later in 1961, Piper Cherokee made over 33,000 units of single engine low wing aircraft. Finally, from 1994 over 1,200 units of the Diamond DA-20 have been produced to meet growing demand for an efficient single engine trainer aircraft. However, with the growing pilot shortage and issues with availability and price of aviation fuel, the cost of flying bears a critical part in total cost:

“The cost of flying is the elephant in the room. It’s the most often cited reason why people don’t take flying lessons.” (Planeandpilot 2014).

Today, the small aviation market situation can be described as follows (Table 4):

**Table 4: The Small Aviation Market Situation**

Issue	Description	Impact
Capacity	Current training fleet capacity insufficient. New pilot shortage demand = 1 aircraft per pilot needed 750 flight hour/year (for 2 years) = 1,500 hr ATP.	Very large demand increase
AvGas	EPA regulatory, or industry eliminates Avgas	Demand acceleration
LSA (Light sport aircraft)	Market grows from reduced regulation limitations (electric propulsion and/or broader training utility)	Competition likely; Demand reduction
Part 23*	Accelerated regulation change including electric technology acceptance	Competition likely; Demand reduction
Automation	1 pilot airliner	Reduced pilot demand
Economy	Variables impact	Plus or minus

*\*Part 23 contains airworthiness standards for airplanes in the normal, utility, aerobatic, and commuter categories. It dictates the standards required for issuance and change of type certificates for airplanes in these categories. E.g., the maximum takeoff weight of an airplane in the normal, utility or aerobatic category cannot exceed 12,500 lb, while in the commuter category it cannot exceed 19,000 lb.*

### 5.5.1 Success Factors

By utilizing advanced current technology SunFlyer’s team (AEAC – Aero Electric Aircraft Corporation) is confident that electric airplanes will soon (within next 2 years) make a breakthrough into the small aviation market due to their ability to synergize available knowledge and expertise in regenerative energy systems. By improving each vital part of airplane manufacturing and design processes (such as motor, battery, solar cells, structure, propeller and general aerodynamics) and at the same time proceeding with certification and agreement of Federal Aviation Authority, very little criticism is left to deny such development possibility.

- a) Motor – highly efficient electric motors have been developed without compromising weight (a new electric motor of 261 kW weighting only 50kg presented by Siemens Corporation will be discussed further in the chapter).
- b) Battery technology – efficient Li-ion batteries, (currently in development – graphite and Si-ion options) are widely used in hybrid systems in both automotive and aviation industries.
- c) Solar cells – compared to semiconductors, expected efficiency from  $1m^2$  is experiencing nearly geometrical progression and yet another advancement may be expected within next few years.
- d) Propeller – innovative solutions in propeller sector made it possible to achieve multi-blade, generating low RPM (revolutions per minute), light weight (carbon fiber), root twist, while variable pitch and root chord assists in energy regeneration in flight.
- e) Federal Aviation Authority –to comply with the safety requirements and regulations scheduled familiarization meetings are conducted with certification plan concurrence and progression to receive Part 21 Standard Airworthiness Certificate (also to be able to operate the aircraft under day – night VFR, visual flight rules).

### **5.5.2 Next generation certified trainer**

*(See Figures 7 and 8)*

According to the CEO of the company, their solar battery equipped certified trainer is designed to have the following properties:

- Cost Effective (Table 6, Sun Flyer hourly operation cost comparison with Cessna 172)
- Safe, airbag seat belts, ballistic parachute safety system
- Easy to fly, benign slow flight, approach to stall characteristics
- Integrated Training System, IPADs, CBT, Simulators, Airplane
- Easy to operate, access doors, simple checklists, readable instruments
- Comfortable seating, ventilation, heating, visibility, entry & exit
- Durable finish, Rugged, Long Ops Life, maintenance and support

Additionally, to further qualify with the regulations, Sun Flyer has a fully working plane model in the Red Bird FSTD (Flight Simulation Training Device) Simulator (Table 5).

**Table 5: Sun Flyer Preliminary\* Specifications**

Gross Weight	1,294 lbs (588 kg)
Empty Weight	580 lbs (263 kg)
Battery Weight	264 lbs (120 kg; 28 kWh)
Pilot and Passenger	450 lbs (205 kg) incl. bags
Wing span	38 feet
Cabin Width	46 inches; 2 seats, side-by-side.
Cruise Speed	60 to 80 knots
Maximum speed	110 knots
Rate of Climb	700 fpm
Endurance	2.5 hours (including optimum solar) 30 minutes reserve
Solar	6.1 square meters, (up to 1.3 kW)
Propeller/RPM	Cruise: 1,400 rpm / Takeoff: 1,900 rpm, noise = 55 dB
Batteries	28 kWh total, battery unit exchange is approximately 5 min.

*\*Specifications are preliminary and subject to change*

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### 5.5.3 Operational Costs

The field research within small aircraft/rotorcraft companies in Japan showed that on average 38.93% of total operational costs consist of aviation fuel, further regarded as AVGAS. While the price of AVGAS varies depending on the region, it is relevant to compare Sun Flyer's and Cessna 172 one-hour costs displayed by AEAC in US, with the same Cessna 172 operated in Japan's training facilities. It is interesting to notice how wide fluctuations are visible through operation of nearly the same aircraft configuration in different locations. Additionally, to present as much comparison as feasible, author considered collecting and supplementing data from his personal flights through local aviation club in Japan.

According to Statista.com, 2015, fuel prices in different countries range from a few cents to just under 10 U.S. dollars per gallon. Gasoline is often regarded as a key driver of a country's economy, as it is the main fuel used in families' passenger vehicles and the automotive fleets of small and large businesses. The United States is the biggest consumer of gasoline on a per capita basis, with 1.22 gallons of gas per person and day. While in US1 gallon costs \$US 2.93, in Japan it is \$ US5.79. However, while difference in fuel price is nearly double, another substantial portion of the total operation costs in Japan is maintenance, professional labor and supplementary aircraft parts (especially if imported, for example Cessna 172 model).

**Table 6: Sun Flyer and Cessna 172 operational cost comparison in US and Japan:**

	Cessna 172 (In US)	Sun Flyer*	Cessna 172 (In Japan, Aero club)	Cessna 172 (In Japan, Training Facility)
Maintenance (800 flight h/year)	\$6,000/year (\$7.50/h)	\$1,000/year (\$1.25/h)	\$15,000/year (\$18.75/h)	Undisclosed
Engine/Motor, Controller Overhaul	\$20,000/2,000 h (\$10.00/h)	\$2,000/2,000 h (\$1/h)	\$60,000/2,000 h (\$30.00/h)	\$60,000/2,000 h (\$30.00/h)
Fuel (\$5.00 per gal*), Oil	\$48.50/h	N/A	\$101.25/h (~300JPY/L)	\$101.25/h (~300JPY/L)
28 kWh Battery Replacement Reserve (\$16,000 per 2.5 year)	N/A	\$8.00/h	N/A	N/A
Electricity (\$0.10/kWh) 10kWh	N/A	\$1.00/h	N/A	N/A
Total	<b>\$66.00/h</b>	<b>\$11.25/h</b> (\$16.25/h if incl. \$5/h FBO)	<b>\$150.00/h</b>	<b>\$290/h (at rate 1USD=120JPY)</b>

- *Sun Flyer estimates are preliminary and subject to change*
- *January 2015 Fuel costs are lower than historical 2 year average*
- *~\$4,000 per battery pack, 1,000 cycles, 4 battery packs, two 7 kWh battery cycles per flight hour*
- *FBO fuel profit margin varies, and may not apply in all cases.*

#### 5.5.4 Critical Analysis

Now, from critical point of view, while Sun Flyer seems to be a revolutionary long-term energy regenerative solution for pilot training and general aviation purposes, numerous issues still remain to be unsolved and there is no 100% guarantee that stated performance data will satisfy Federal Aviation Authority regulations within the next 2 years. Then, while there is a great interest in developing rechargeable lithium batteries with higher energy capacity and longer cycle life for applications in portable electronic devices, electric vehicles and implantable medical devices (Chan, 2008), there is a theoretical specific capacity limitation derived from lithium (or any other material used in batteries today). Nevertheless, considering applied technology and detailed assessment of safety requirements there is a high possibility that solar panel re-chargeable aircraft will soon become a widely used market product in the small aviation industry. There is no doubt that electric propulsion is a next step for small aircrafts, even if initial implementation step will be done through hybrid system applications. Furthermore, while scientists in Li-ion battery sector are working on larger capacity, lighter and safer batteries, Sun Flyer can be a just-in-time solution before a sustainable energy capacitor is presented, which is not only suitable for small aircraft/rotorcraft, and easily replaceable, but also is equally efficient in terms of range when compared to the same weight and size of AvGas alternative.

## 5.6 SolarStratos – Manned Solar Flight at the Edge of Space

*(Calin Gologan, PC Aero, and George Bye)*

SolarStratos is an experimental solar panel equipped aircraft designed to break the world record of height (24 km), range (all day) and flight time with the ability to reach middle of stratosphere with the final goal of 80,000 feet. SolarStratos also is part of the research program for Sun Flyer solar – electric aircraft.

SolarStratos project is a result of a first version of electric aircraft Electra 1 (by PC-Aero) that further resulted in concentration to develop a fully certified solar powered aircraft (under collaboration with Bye Aerospace). The unique features of SolarStratos aircraft are completely redundant electric power unit (one engine with two rotors), automatic variable pitch propeller, extra light batteries together with solar batteries (two independent battery systems) and full integration of the autopilot with panel avionics. By utilizing carbon fiber material, the total weight of the airframe is only 14kg, while wide span structure gives glide ratio over 40 (at high altitude goes down to 30). (See Appendix C for SolarStratos Data Sheet).

### 5.6.1 Constraint analysis

The aircraft to loiter at altitudes greater than commercial air traffic, generally within the Earth's stratosphere, requires the wing to generate a lift force large enough to counteract the aircraft's weight allowing it to maintain a level cruise. However, flight at this altitude presents a number of challenges. The first and most important relates to the density of air at an altitude of 21.3 km, which is approximately 17 times less dense than that found at sea level conditions. In order to generate enough lift to maintain level flight at altitude, it will be necessary for the aircraft to travel approximately four times faster than would be required utilizing the same airfoil at sea level, a consequence of the fact that lift force is not only a function of local air density, but also a function of the aircraft's velocity squared. Furthermore, the conversion of solar radiation into electrical energy through the use of photovoltaic modules is to be considered. The increasing intensity of solar radiation with altitude, combined with an unlimited energy source, means that solar energy lends itself well to this application (Emeraldinsight.com, 2015). SolarStratos uses a specific chamber to test solar battery efficiency at high altitudes. Still, detailed attention is oriented towards choosing specific solar cells, since while best of them can achieve up 44% performance ratio at low

altitude, high altitude applications widely fluctuates. Finally, due to lot of inertia in the battery itself, low temperature is also an issue.

### 5.6.2 Commercial application

The general philosophy of the project states that: “you should use what you can get for free”, hence, the principle of solar-regenerative concept (or energy harvesting) is to start the flight and finish it with fully charged batteries. To achieve that, a wide span allows for conducting flight at low speeds, while dual engine system and three-blade electro-automatic pitch propellers assist to achieve most efficient lift to drag ratios. While cost structure currently remains undisclosed, it is logical to assume that first prototypes (especially in aviation) are always expensive and time consuming. Nevertheless, the future commercial application is considered, by implementing pressure suits with oxygen supplies. Then, there is no necessity for flexible solar cells: by embedding sonar panels with the glass fiber plastic, approximately 90% of the wing can be used for solar battery application.

**Figure 7: Airbus E-Fan**



**Figure 8: Sun Flyer**





## Chapter 6

### Transferability towards an Electric Aircraft Business Model

*(Field Research 2: Electric Aircraft Symposium (IX) 2015, California, US Continued)*

#### 6.1 Introduction

Transition of innovative technology, especially in aviation industry, is a complicated and time-consuming process mostly due to high operation risk factors as well as particularly demanding safety requirements established by aviation authorities. In this chapter a successful case of certified electric aircraft is analyzed and further discussed to support the following research question:

1. What are the political, economic and technical challenges that restrain the small aviation industry's move toward smooth sustainable transition?

The key findings explain working strategy for implementing electric propulsion systems with additional emphasis on certification and marketization policy. Further, the energy storage issues are discussed through fault assessment analysis of Li-Ion batteries. Finally, innovations in environmentally sustainable Li-Ion battery are presented as a next step for potential sustainable energy storage solutions.

#### 6.2 Certified Electric Aircraft

*(Dr. Tine Tomazic, Pipistrel)*

Pipistrel, founded in 1989 in the former Yugoslavia has been a private aircraft producer of alternative aviation for the last 25 years. During challenging and precarious changes in political regimes of the country, the company has achieved remarkable targets in implementing the electric aircraft concept in practice. On one side Pipistrel's fuel-efficient aircraft has already proven to achieve the best fuel efficiency and range available on the market. For example, the Pipistrel Sinus has a super-low fuel consumption of less than 10 liters per hour (2.6 gph) at a high cruise speed of 200 km/h (110 kts) able to easily fly over 1000 kilometers (540 NM) already with standard 60 liter (16 gal.) fuel tanks. With optional long-range (100 liters; 26 gal) fuel tanks the range with reserve goes beyond 1650 km (890 NM) (Pipistrelsi, 2015). On the other hand, the latest model "WATTsUP" has become a fully certified electric aircraft currently being used by pilot training facilities. Pipistrel has a

distribution network covering most of the countries and is successfully continuing its mission to convert general aviation aircrafts to electric propulsion. However, a minor correction is necessary: according to the company “It’s not about converting, rather than starting engineering from the initial roots”. Generally, if only propulsion is changed, the aircraft will still use the same HP (horse power); therefore, overall use of alternative energy will also remain unchanged.

The key benefits of WATTsUP model are quick turn-around times, the working model of energy recuperation and compliance with requirement for 2000 hours of TBO (time between overhaul). Furthermore, energy storage is completed in two independent battery models, with 3 enclosures weighting 20kg each including all supportive electronics. From the safety perspective, battery box does not have touch connectors, while temperature sensors constantly inform about the battery condition. While it is common to display battery charge cycle count (full or short cycle), company research revealed that state of health indication is much more efficient way to monitor status of the battery. Finally, even if one battery module goes offline, the aircraft is still capable to maintain flight without losing performance.

### **6.3 WATTsUP Delivered Performance**

At this moment, Pipistrel’s WATTsUP electric aircraft has maximum takeoff mass of 550kg (1212lbs), a battery system mass of 126kg (277lbs), effective energy density of battery system of 150Wh/kg and is able to fly for one nonstop hour in traffic patterns (where continuous takeoffs and landings are performed) including approximately 30 minutes of safety reserve. The aircraft powered by highly efficient SIEMENS electric motor of 60kW (2000RPM) with asymmetric airfoil delivers 650 feet of ground roll, 1000 feet/min climb performance and cruise L/D 15:1 ratio. Furthermore, propeller (fixed pitch diameter 71 inch) has a sufficient reverse thrust to act as an air brake, while energy recuperation is increasing with the speed and angle increase.

Of course, 1 hour plus reserve is still far from the 5 to 6 hours of conventional internal combustion engine. However, the aircraft powered solely by electric propulsion is certified and serves specific training purpose. In general, effective training session of 1 hour is reasonable, considering the fact that battery swap takes about 2 minutes, while 45 minutes is enough to fully charge a battery. Then, by being able to simply turn off the engine while

waiting on the taxiway for clearance, pilot has an advantage to log only actual flying time without losing 5-10% of time on the ground, which is normal for fuel powered aircraft. Hence, with two battery packs a student pilot is able to fly continuously without a delay.

#### 6.4 Efficiency Concept Implication

Based on Pipistrel's philosophy, total efficiency comes from a sum of potential partial efficiencies. Saying that, application of generic model and optimization of flying styles and techniques as well as which propellers (fixed, variable pitch, constant speed) to use for control are all important factors to consider if high efficiency is in priority. Furthermore, since airframe has to be tailored to the electric propulsion with the synergetic effects, a completely innovative approach to the airframe should be studied. Finally, with the company's future vision of gradual conversion of its aircrafts to hybrid and electric propulsion, it is critical to think of every detail to make each kW matter.

#### 6.5 Electric Propulsion Strategy, Certification and Marketization

*(Dr. Frank Anton, Siemens)*

Siemens - a global powerhouse of electrification, automation and digitalization, is one of the world's largest producers of energy-efficient, resource-saving technologies such as power generation and transmission and medical diagnostics (Siemens.com, 2015). However, while there has been an exceptional technology outburst, no disruptive innovation in engines has been seen since invention of internal combustion engine. The latest model of Siemens electric engine designed for small electric aircraft application has a power output of 261kW with the weight of only 50Kg. Such achievement was reached by implementing 3D and 2D software solutions - Siemens PLM (Product Lifecycle Management). Therefore, the key advantages that derive from such electric motor are (Table 7):

**Table 7: Advantages of the Electric Motor**

Propulsion	Light, efficient, reliable, safe, silent
E-machine	> 95%    >6kW/kg
Inverter	> 20kVA/kg
Controls	Safe and redundant
Cooling	Light, small and adapted to airframe
Combustion Engine	Light, low consumption and emissions
Energy	Safe, integrated with airframe, light, optimized for energy or power density (depending on application)

*Source: 9<sup>th</sup> Annual CAFE Electric Aircraft Symposium, MAY 1,2 2015, Santa Rosa, California*

The prospect of Siemens in promoting electric aircraft is displayed in two steps:

- a) Innovate, certify and spread electric aircraft in the global market
- b) Develop propulsion for large electric aircraft.

According to the company, while there seems to be a bright future for small electric aircraft, electric propulsion for large aircraft has a serious disadvantage in terms of battery storage. Nevertheless, for the purpose of environmentally friendly solutions for the aviation industry, development of hybrid systems is in progress, since based on company's research distributive propulsion is considered to be more efficient. Siemens projects to be able to produce hybrid electric propulsion systems for regional size aircraft with 60-100 seats by the year 2035. Potential benefits of hybrid systems are less noise, operational advantages, better fuel maintenance and feasibly redundant energy sources. Furthermore, serial hybrid electric propulsion systems for aircraft is currently under development (type of aircraft, date of launch, collaborative companies remain undisclosed) with two redundant power systems of up to 1 MW to assure safety and required performance. Yet, two key questions by the author remain to be unsolved:

- 1) While based on energy conservation laws it is clear to see the benefits of hybrid Toyota Prius due to four rotating wheels to support forward motion (and gravitational forces also act in favor), however, placing a hybrid system in the jet aircraft is yet adding superfluous complexity levels with questionable efficiency benefits.
- 2) It was stated that in the highly unlikely event of hybrid system failure the principal fuel engine will result in surpassing normal operation conditions, hence, the question of redundancy levels regarding overall hybrid system safety in potentially large aircraft is still open-ended.

## 6.6 Energy Storage Constraints

*(Neil Johnson, Navitas Systems Advanced Solutions Group)*

Today, with the exception of some recent attempts to potentially apply renewable energy concept in small aviation, the industry is solemnly powered by petroleum. The history of electric vehicles shows that while first electric vehicle was manufactured in the middle of 19<sup>th</sup> century (yes, 19<sup>th</sup>!), due to cheap price and convenient dependency on oil, the industry still massively favors petroleum every time another electric car is being introduced (same

happening in marine industry). Oil competes directly against renewables in only about 5 per cent of the market – those places where oil is used in generation – particularly the Middle East (Saudi Arabia uses oil for 55 per cent of its electricity needs, and the Middle east as a whole 36 per cent), and in the Caribbean (Jamaica 91 per cent) (Renewconomy.com.au, 2015). Nevertheless, when talking about energy storage in Li-Ion batteries for electric engine applications, opinions vary at great extent. Yet, two opposing viewpoints of whether Li-Ion (or other base material) batteries have a disruptive future for applications in practice will be further presented and analyzed. Undoubtedly, Li-Ion batteries have experienced great success in consumer world for application in portable electronics sector, however, in transportation industry the overall situation is different. Navigant Research estimates in a new forecast that light-duty vehicles make up 95 percent of that total, and that the vehicles we drive everyday will shortly cross 1.2 billion. Hence, just 2.5 percent of those will be battery electric, 8% plug-in hybrid, or fuel-cell vehicles--the rest will run on gasoline or diesel fuel (Bioage Media 2015). Therefore, while battery technology used in fully electric vehicles of Tesla Motors and Nissan models is being widely applied in both small aviation aircraft design and large aircraft electronic systems, number of Li-Ion based battery limitations have to be analyzed and tested prior to any permanent conclusions can be identified.

### **6.7 Fault Assessment Analysis of Li-Ion Batteries**

- Mechanical problem – high capacity Li-Ion are still too heavy and there are significant installation concerns for the medium size jet aircraft.
- Chemical poisoning – fire of lithium battery apart from releasing an immense thermal energy, fumes are highly toxic and critically dangerous for human. Moreover, lithium batteries contain oxidizer and cathode active materials that might act as an additional trigger for fire, especially if placed near fuel tanks.
- Thermal concern – numerous tests by FAA of Boeing 787 Dreamliner accidents with Li-Ion battery fire on board during flight has revealed that initial trigger was caused due to internal battery fault. Furthermore, extinguishing Li-Ion battery fire onboard is a vastly complicated safety issue.
- Utilization concerns – there is a high environmental issue of how to properly recycle timeworn or faulty battery cells.
- Energy capacity - computation of the battery pack capacity is an issue. Compared to a fuel tank for internal ignition engine, a Li-Ion battery pack is sensitive to performance

“exercises”, since their voltage produced goes down with power application frequency, which in turn increase battery heat and also decreases fault tolerance.

- Other hazards – Li-Ion battery, especially of high capacity, remains to be a hazard of self-ignition and a source of electrocution.

## 6.8 Environmentally Sustainable Li-Ion Battery

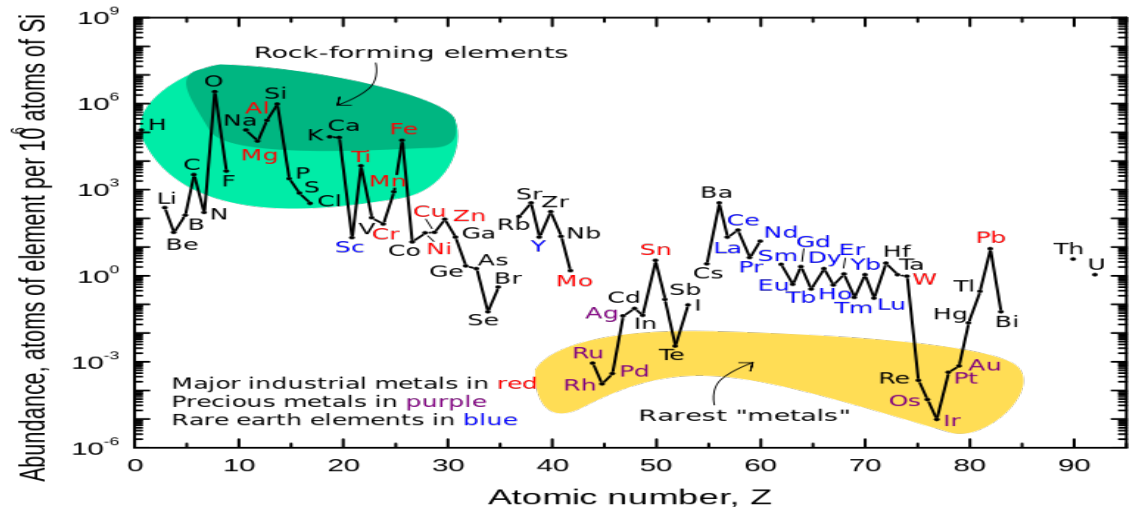
Dr. Zachary Favors, ZAF Energy Systems, “Towards Highly Scalable, Environmentally Benign, High-Performance Si-Based LIB Anodes for Next Generation Li-Ion Batteries”

*(Note: the next paragraph was acquired and re-adjusted with generous permission of Dr. Z. Favors to further enhance the research with additional in-depth work on future development of Li-Ion batteries).*

Recently, potential anode material replacements for graphite have acquired significant attention by both academia and the industry. Graphite offers a low discharge potential (which is good for LIBs) and a theoretical capacity of 372 mAh/g. Carbon allotropes such as CNTs and graphene have shown to produce higher capacity but may lack in scalability. Then, while such material as tin has conductivity of theoretical capacity of 1000 mAh/g, it is quite costly as a raw material and has a low melting temperature, making it difficult to process. Furthermore, Germanium has a relatively high theoretical capacity relative to graphite, yet the excessive cost alone makes this material unfeasible on a large scale.

Silicon, at room temperature has a capacity second only to that of Lithium, at nearly 10 times that of graphite while still offering a low discharge potential. Additionally, Silicon is the second most abundant element and is relatively low cost raw material for synthesis of silicon-based anode materials for LIBs (See Figure 9). Traditionally, silicon is produced via carbon-thermic reduction in electric arc furnaces at temperatures as high as 2100 Celsius that require immense amount of energy to reduce silica to silicon and result in substantial CO<sub>2</sub> emissions. Therefore, for the purpose to produce silicon in a sustainable manner a carbon-free alternatives that require significantly lower energy budgets with recyclable byproducts have to be considered. The researcher sees sand as a viable source of silicon that at the same time enables to reduce required energy for production processes. However, Silicon still faces number of issues, such as significant volume fluctuations, SEI (Solid Electrolyte Interface) layer degradation and low conductivity as a semiconductor, which as a result have prevented it from widespread commercialization.

Figure 9: Abundance of Materials



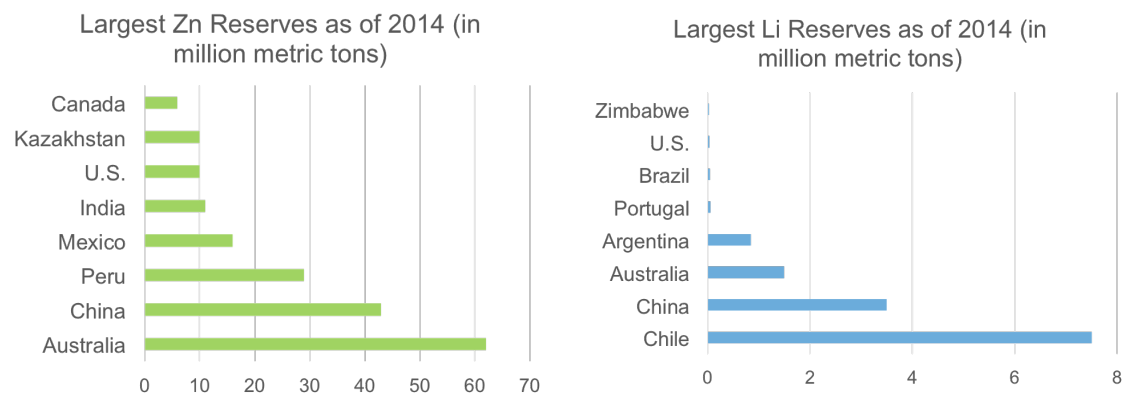
Source: ZAF Energy Systems, 2015

While proposed Silicon based technology is still in the condition of theory testing in practice (R&D), ZAF Energy Systems has developed what appears to be a breakthrough in battery technology by utilizing Zinc material (Table 8). According to the company, ZAF's zinc air battery pack enables a rapid adoption of electric vehicles that in turn has a high application potential in small aviation industry as well. Apart from being non-flammable, (which is one of the primary concerns in aviation safety and regulation requirements) the battery potentially has a double capacity and is four times cheaper in production compared to Li-Ion based versions:

Table 8: ZAF Zinc Air Battery Pack

	Lithium-ion	ZAF
EPA range (miles)	265	527
cost	\$40,000	\$10,608
weight (lb)	1100	1090
battery power (HP)	395	420
energy (kWh)	85	156
lifetime miles	200,000	250,000
cost/mile	\$0.25	\$0.06
Safety	Flammable	Non-flammable

Furthermore, in terms of resource availability, Zinc global reserves outstand Lithium by millions of tons and are found in most of the continents in wide abundance (see Figure 10 for Li versus Zinc Reserves). Certainly, there is still a lot of testing to be done and the key concerns are present of whether effective scalability without losing performance is achievable; yet, the prospect of finding more efficient alternative to Li-Ion is in progress.

**Figure 10: Zinc and Lithium Reserves**

Source: ZAF Energy Systems, 2015



## Chapter 7

### Case Analysis: Application of Sustainable Aviation Practices in United Nations Humanitarian Air Service (UNHAS)

#### 7.1 Introduction

The case analysis of UNHAS was chosen to emphasize critical issues in the global scale organization, where air charter operations directly impact volume of successful international rescue missions. Japan, as an active aid provider and second largest financial contributor to UN (10.833% of UN Peace Keeping Budget, Mofago.jp 2015), by applying technological innovation in aviation industry might further increase the value and efficiency of its international aid in a long term. The findings in this chapter discuss the current challenges of UNHAS that will further assist in highlighting how Japan's example could influence first steps toward transition for sustainable aviation.

#### 7.2 Key objectives

- ✓ Describe currently growing role of aviation in United Nations operations in low accessibility humanitarian missions areas
- ✓ Reveal major issues within UNHAS functions and analyze organization's financial statement as well as provide an insight into decision making process for distribution of available funding resources
- ✓ Basing on OIOS (Office of Internal Oversight Services) latest internal report, uncover critical problems of UN aviation sector, discuss available recommendations and present potential development of innovative managerial, financial and technical strategies for improvement of current unsatisfactory condition of UNHAS operations
- ✓ Prepare a brief strategic practical proposal on progressing the quality of operations, fund distribution and efficiency improvement for liaising procedures between leasing air charter companies and UNHAS

### 7.3 UNHAS in UN

United Nations Humanitarian Air Service (UNHAS) is one of five major (Emergency Response, Nutrition, Procurement, Food Security Analysis, Logistics) United Nations (UN) facilities directly managed by the World Food Program (WFP). For the last two decades it has provided humanitarian air aid to numerous inaccessible emergency sites around the planet. The global network of currently active UN countries where UNHAS services extends are Afghanistan, CAR, Chad, Democratic Republic of the Congo, Iraq, Ethiopia, Ivory Coast, Niger/Mali, Mauritania, Somalia/Kenya, South Sudan, Sudan and Yemen. In addition, by implementing Emergency Response Plan, UNHAS may provide air services to literally any emergency site upon request, considering that available resources have been approved for the particular location in advance by the commission.

### 7.4 UNHAS Services and Operations

UN Humanitarian Air Service serves to nearly 1,300 agencies and, on average, operates 54 fixed wing aircraft and 160+ helicopters in different areas that relocate more than 350,000 passengers yearly. Furthermore, it provides passenger and cargo services to the *entire* humanitarian communities mostly in remote location with lack of infrastructure or that are too dangerous for normal commercial air operators. In most cases UNHAS act as a last available alternative to reach the most demanding and hardly accessible locations to provide variety of services such as:

- a) Air support to WFP logistics: food airlifts and airdrops, emergency deliveries of necessary supplies;
- b) Strategic airlift operations: specific cargo flights for UN agencies, participating NGO's and active contributors;
- c) Security and medical evacuations: for United Nations Department of Safety and Security UNDSS (International flights);
- d) Third party services for air-chartering for other agencies including those within UN, such as UN High Commissioner for human rights;
- e) UNHAS: upon request of UN Country Team and Humanitarian Coordinator (transportation of UN high commission members to the hot-spots). This service also includes VIP executive passenger services (revenue generation services).

Being driven by demand, equal access for UNHAS services is based on the first come first serve option applicable to all humanitarian agencies, and, since the organization is largely funded by international private and governmental donors it's decision making process for distribution of available financial resources raises the main issue in the complete structural system of the organization.

## 7.5 Financial Review

Air charters that were utilized to send peacekeeping troops to conflict zones consumed almost one third of UN budget in 2011, while according to the latest audit conducted by Office of Internal Oversight Services the number is fluctuating around \$2.13 billion. Specifically for UNHAS operations (as officially recorded), the total cost amounts for US\$ 183 million for the average of seventeen countries that received the large portions of the financial resources available.

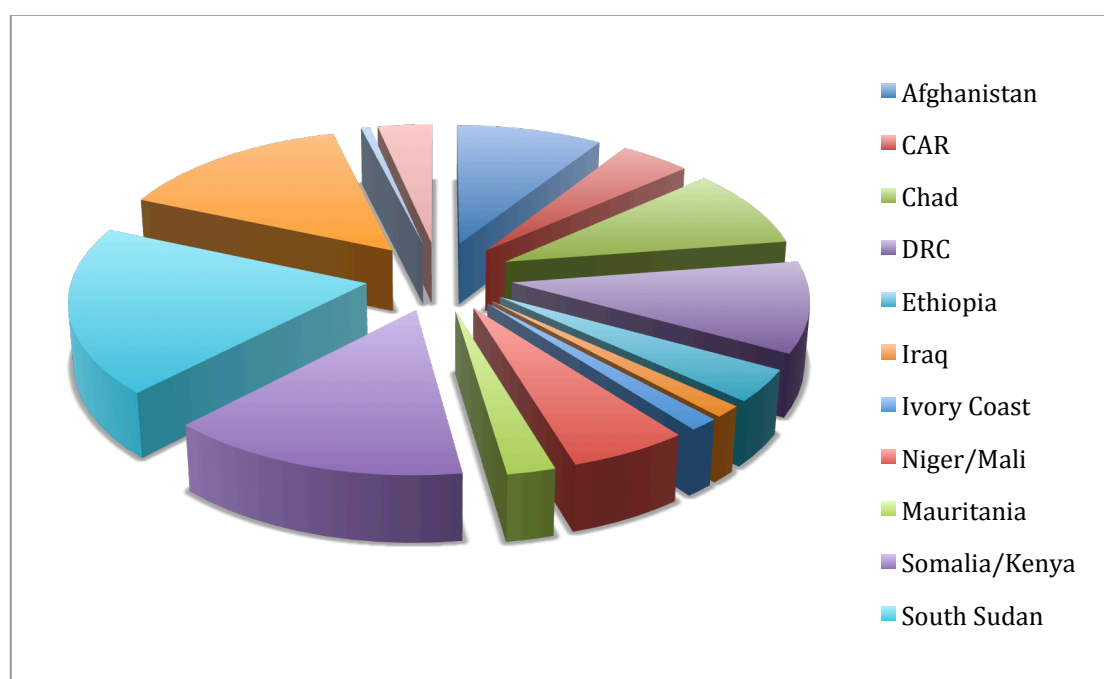
Table 9 presents the costs, budget distribution, amount of aircraft employed and hours flown for both passenger and cargo transportation. *However, since some of the commitments in 2011 were not reported in 2012 balance, and some commitments in 2012 were not completed during the annual reporting process, the actual funds carried over and surplus available for 2013 will differ in the next report.*

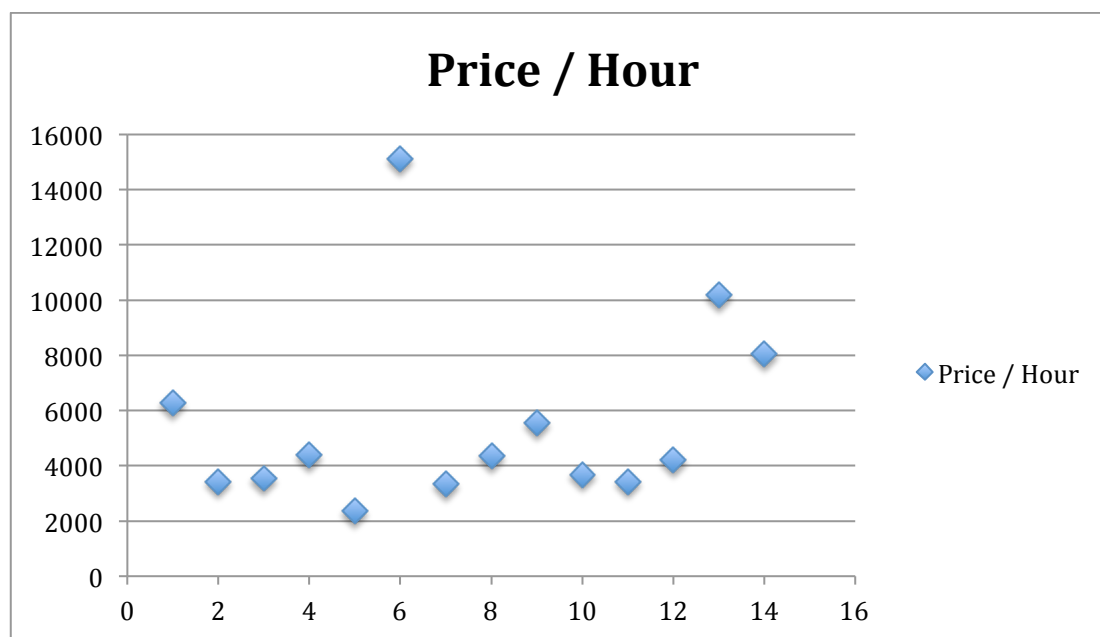
Regardless of the fact that each aircraft in general differs in its carrying capacity, fuel consumption and operation cost, by following the relationship between overall mission costs in each country and hours flown it becomes possible to project the correlation of average price of hour flown.

Table 9. Distribution of the resources for 2012 UNHAS operations

	Budget 2012 US\$	Resource Mobilized 2012 US\$	Project Costs 2012 US\$	Chartered Aircraft	Hours flown	Pax	Cargo (mt)
<b>Afghanistan</b>	22,076,522	15,712,174	15,156,034	2	2,417	26,550	75
<b>CAR</b>	7,395,795	7,674,484	7,374,484	2	2,157	14,472	175
<b>Chad</b>	17,616,692	18,592,582	15,120,056	4	4,268	65,053	179
<b>DRC</b>	16,392,969	20,774,006	17,436,139	4	3,978	32,506	227
<b>Ethiopia</b>	7,538,783	9,099,924	6,240,727	3	2,633	10,381	30
<b>Iraq</b>	5,052,454	2,284,064	2,284,064	1	151	1,106	39
<b>Ivory Coast</b>	3,147,262	2,717,204	2,416,366	1	722	5,963	79
<b>Niger/Mali</b>	10,034,591	11,561,790	9,626,694	2	2,210	19,329	57
<b>Mauritania</b>	4,970,921	5,006,256	3,892,495	2	699	3,700	15
<b>Somalia/Kenya</b>	30,465,821	31,433,298	24,258,357	7	6,588	37,776	271
<b>South Sudan</b>	43,839,086	32,483,392	32,204,511	13	9,360	88,224	396
<b>Sudan</b>	34,533,260	31,974,629	24,313,813	8	5,777	44,731	229
<b>Yemen</b>	1,120,758	1,359,718	916,334	1	90	346	0
<b>Global</b>	5,632,262	6,286,452	5,631,996	3	700	3,228	186
<b>Total</b>	<b>209,817,177</b>	<b>196,959,973</b>	<b>166,872,070</b>	<b>53</b>	<b>41,750</b>	<b>353,365</b>	<b>1958</b>

Figure 11. Budget Distribution by country in 2012



**Figure 12: Price per hour correlation table**

Therefore, with the exception of Iraq (as one of the most active military operation zones) and Yemen, which has encountered food crisis and was activated by UNHAS to be carried out under a special operations program, the average price fluctuates around \$4,000/hour. Consequently, since UNHAS leases its aircraft from commercial operators and, according to UN general conditions for aircraft charter agreements the carrier is responsible for the airworthiness and continuous maintenance of the aircraft in operation yet is exempted from most applicable taxes (compared to normal air charter operations), depending on type of plane used, approximately 40% to 50% of operating cost consists of aviation fuel.

Compared to the prices in the early 90's, jet fuel cost six times more in 2013, while the major increase occurred within the last 10 years and raised the cost from US\$1/gallon up to US\$ 3,4/per gallon. To summarize, since the fuel market is highly volatile, there is a strong tendency that general fuel prices will continue to escalate in the upcoming years. Even though the technology is finding its way to increase the efficiency of the engines, the average age of the aircrafts operated by UNHAS is 20 years, hence, the consumption of fuel will continue to be one of the critical financial expense for every hour flown regardless the type of aircraft (Figures 11 and 12).

## 7.6 Contracting and aircraft leasing

As a general policy, the UN Procurement Division (PD) announces contract awards for the air charter companies that were chosen on the number of requirements suitable for UN operations. However, according to the recent OIOS audit report, the actual choice of air charters are, in many cases, not chosen according to preset conditions, which in turn considerably affects the balance sheet of UN.

In 2013 UN PD signed 120 contracts with multiple air charters accounting for almost US\$ 0,5 billion (sum of new and continuous awarded contracts until October 2013 is equal to US\$ 466,629,274). Hence, the balance sheets indicating financial situation of aviation sector in United Nations is published with different reporting methods, which raise complexity level, yet might be widely interpreted depending on the targeted audience (in this case donors and both private and governmental financial support providers). Since UN overall budget might be distributed for number of internal departments within the organization and not represent the actual expense, leasing of aircrafts from commercial operators remains to be one of the most important and critical issues of UN financial feasibility and efficient allocation of scarce resources.

## 7.7 UN Organizational structure and decision-making

Air assets for United Nations air operations are acquired on a mission-by-mission basis and are financed by individual budgets approved for each mission in support of its mandate.

The Department of Field Support (DFS) manages overall fleet planning and acquisition.

The Air Transportation Section (ATS) of DFS is responsible for oversight over the global budgetary and programmatic aspects of air operations.

The Procurement Division (PD) of Department of Management (DM) is responsible for the efficient, effective and economical administration of the Secretariat's procurement function and related support services.

*(Acquired from OIOS report published in December 2012).*

Since each mission is being financed separately and there are five different departments managing every operation, such decision making process places heavy load on every responsible body and drastically decreases the efficiency of resource distribution and ability to respond rapidly to emergency situation.

## 7.8 OIOS Audit background

The Office of Internal Oversight Services (OIOS) audited UN air charter service agreements and prepared analysis of its contract administration and acquisition processes. During the inspection, the following conditions were present:

- ✓ 222 aircraft (164 rotary-wing and 58 fixed-wing) deployed;
- ✓ 90 active contracts valued at approximately \$1.5 billion;
- ✓ Expense of air transportation services in 2011 (lease/fuel/other) was \$863 million that is equal to 20% of all major goods and services secured.

The objectives of the audit were:

- a) Efficient and effective operations;
- b) Accurate financial and operational reporting;
- c) Safeguarding of assets;
- d) Compliance with mandates, regulations and rules.

## 7.9 Audit findings and recommendations

In December 2012, OIOS published United Nations air services overall organization and performance evaluation report, which exposed numerous faults and managerial misconducts that considerably decreased the efficiency and potential maximum output for each air operation conducted within the year. According to OIOS, the UN Secretariat's governance received the lowest possible evaluation in terms of governance and risk management as well as showing an inability to provide cost effective and efficient contract management processes and reach advantageous agreements with the air charter providers. As a result, 11 recommendations, divided into three critical and eight important (combined) issues were drafted to address the current situation with possible suggestions for continuous improvement. Those include:

Critical:

- ✓ Clearness of terms and requirements presented for potential air charter providers should be guaranteed by Department of Field Support (DFS), which in turn should

allow for the vendors to propose innovative cost effective solutions and improve overall compliance with UN requirements.

- ✓ DFS should enforce proper documentation of missions and provide detailed approval of air charter requests based on previous experiences to improve quality and control.
- ✓ DFS together with Office of Central Support Services (OOSS) should construct an effective strategy that would improve each acquisition action with air charter provider. As mentioned in both OIOS and IO watch reports, numerous concerns has been raised regarding the credibility of the choice of most suitable air charter for the particular missions. For example, for the last 5 years, special attention was given to Russian large operator company U-Tair, which continues to receive large portion of contracts while its cost effectiveness is not often justified, and often raises strong discussions in terms of corruption within UN responsible bodies. In many cases smaller vendors are not even given an opportunity to present their proposals.

Important:

- ✓ Aviation market standards should be followed to guarantee rationality of proposed prices for potential vendors. Furthermore, collusion between the vendors is another important issue, which is complicated to track and expose, especially in times of emergency.
- ✓ DFS with OOSS should more closely moderate the registration process and improve monitoring activities to provide strict compliance with the timelines as well as track balance condition of operators under 'special approval', which are based on case-by-case financing.
- ✓ DFS and OOSS should continue to utilize only the latest standards for air charter agreements that have been updated, audited and investigated; hence, the acquisition strategy may be closely monitored and regularly modernized.
- ✓ Finally, by utilizing the newest information technologies DFS should develop effective risk management systems that increase air charter operations quality and correspondingly provide transparency for each operation.



## 7.10 Strategy Evaluation

Based on currently existing structure in UNHAS as one of the major United Nations bodies, to propose innovative solutions for improvement of managerial, organizational and effective distribution of the resources for the air services, the following considerations should be taken into account:

- 1) In principal, the current condition of air charter agreement process is in its nature contradictions to peacekeeping ideology. The funds acquired from various donors are, with immense disadvantage to UN budget, spent on satisfying the financial requirements of air charter operators. Since all UN air charter agreements are based on commercial terms, UN represents just another client with benefits (air operations for UN are under tax exemption policy) to any commercial air operator. Subsequently, by directing more than half of its resources to purchase aviation fuel from the third party, UN, in fact, on a large scale exemplifies a B2B (business-to-business) commercial model, with the exception of investments being provided without a ROI (return on investment) condition.
- 2) Existing decision-making process adds complexity, is time consuming and lack efficiency. However, by acting under peacekeeping vision, serving to almost 1,300 various NGO's and other agencies, providing commercial contract to air charter operators and being constantly dependent on unstable funding, UN air services will most probably continue to face difficulties especially in highly volatile aviation market, unless comprehensive revision of strategy of contracting is attempted. Canadian, American or Russian aircraft / helicopters under UN program that are sent to an approved zone for humanitarian purpose is a direct revenue (free of tax) to commercial operator and third party jet fuel dealer, which is paid by the donor country; while such a model is perfectly suitable for business operations under normal investment financing, being justified as a humanitarian mission might not satisfy the future donors in the upcoming years.
- 3) By remaining the power of influence on global political arena, UN should consider developing a new model of contracting with the air charters, based on governmentally monitored resources provision, and, by enabling political tools (with humanitarian perspective) attempt to access and reach reasonable agreements with

the first suppliers of the currently most expensive and useable resource – aviation fuel.

### **7.11 Conclusion**

This chapter serves as a brief summary of UNHAS air operations role in United Nations. By exposing critical issues within the organizational structure and managerial processes, selected figures and evidences were presented to assist the argument of critical condition and financing problems. Nevertheless, concentration on developing sustainable operations is especially important for the organization that does not have a stable financial income. While UN stands for the uppermost humanitarian and peacekeeping provider available today, highly commercialized operations and air charter leasing practices continues to place a heavy burden on the publicly criticized increasing budget spending. Unless UN operations are originally structured to be business oriented, the political tools remain to be the strongest asset, which if properly utilized, might win UN critically required benefits in terms of resources provision. Saying that, since approximately 40% of air operations consist of aviation fuel, United Nations General Assembly should develop a strategy to seek for more efficient management of aviation alternatives. Yet, in a meanwhile negotiation for agreements with the primary supplier to substantially decrease the price of the fuel in a long term is critical.

## Chapter 8

### Conclusion: A Framework Model for Sustainable Light Aviation

#### 8.1 Summary of the Research

The relationship between aviation and tourism is intertwined on different levels and is directly affected by increased demand in air travel and growing volume of passengers that continue to negatively impact the environment. The key objective of the research was to construct commercially feasible, eco-oriented flight operation business framework by applying renewable energy concepts that may substantially reduce environmental impacts, such as CO<sub>2</sub> emissions, toxic fuel wastage, and water pollution as well as address noise issues. Japan was chosen as a suitable country model where application of renewable energy concept in small aviation industry may be implemented most efficiently.

Prior to field research in both Japan and the US, four principal research questions were stated in Chapter 1:

- 1) What are the trends and projected tendencies of air transport industry in Japan?
- 2) Which transportation segments do small aviation operators occupy, and why they act as a critical link to the future of general aviation?
- 3) How imposed governmental directives address environmental challenges in aviation industry?
- 4) What are the key factors that influence the link of aviation tourism to an effective environmental policy?

The research outcomes have shown that (1) price pressure continues to be a factor resulting in decreased prices and yields have consistently dropped. For airlines to remain vibrant cost control is an ever-growing concern, especially such as high fuel charges and costly delays at overcrowded airports that impact negatively on the airlines bottom lines. The way individual commercial airlines react to and implement strategies across the globe will determine carrier performance and their capability to survive. For Japan, Japanese government is continuing to take initiative action to improve aviation industry and further develop air transportation within the region.

Next, the transportation segments that are occupied by small aviation operations (2) can be grouped into pilot training facilities, charter flights, specific use aerial services, business aviation, medical services, aerial sport activities and agricultural applications (further varying in type of service and specific purpose of utilization). Therefore, while organizational and planning problems in a small aviation industry is less complex and might execute higher degree of flexibility, the majority of exiting barriers and limitations are similar to any aircraft. Therefore, some of suitable optimization techniques applied in the airline industry should be carefully examined and re-designed in terms of functioning algorithms for further planning and operations.

The findings on governmental directives that address environmental challenges in aviation industry (3) revealed that with the global warming and CO<sub>2</sub> emissions level becoming a center of attention as a critical and highly sensitive environmental issue, MLIT challenges to implement new effective practices to further advance Japan's transport infrastructure through:

- Supporting transport to and from remote islands and enhancement and optimization of airport operations;
- Accelerating the reception of business aviation;
- Initiatives to reduce CO<sub>2</sub> emissions in aviation; and
- The Promotion and Dissemination of Alternative Fuels in Aviation (Biojet fuels).

Finally, the key factors supporting the link between aviation tourism to an effective environmental policy (4) are:

- a) Synergy of research - a necessity to utilize complex research data simultaneously for initial problem definition processes and environmental policy agenda formulation;
- b) Global information network - faster communication opportunities open horizons for more sophisticated interaction among different ministries, NGO's, business structures and third party institutions as well as assist in building international multi-dimensional networks;
- c) Distinctive technology craft - information technology, nano-technology, and molecular science are accelerating through global connectivity channels and generate global complex interactions across sectors, areas, and societies;

- d) Environmental business model - the concepts of the consumerism and its tools for successful implementation, if adjusted accordingly, may benefit in boosting the response and overall participation of the actors in environmental policy enforcement; and
- e) Bridging – consulting agencies, while initially operating independently, are capable to effectively search, adapt, rationalize and further implement sophisticated academic achievements primarily to the governments, public and participating businesses by utilizing not only acquired research data, but also applying market based instruments and competitive market tools to the local and global markets.

## 8.2 Findings: Field Research 1

There are five principal reasons why Japan was chosen as a potential testing and development ground for implementing sustainable renewable energy solutions in small aviation industry. These are: safety awareness, technological advancement, fuel resource dependence, geographical positioning and national pilot shortage.

During the first field research, Japan's small aircraft / rotorcraft air operators were analyzed to reveal economic relationship between aviation fuel, price structure and CO<sub>2</sub> emissions in aviation industry. Field research study revealed that fuel consumption varied from 35% to 45% of total operational costs, while there were no traceable environmental practices adapted by the companies. However, the overall operations of Japanese aviation companies held one of the top global ranks in terms of industry safety, high-end quality system maintenance, extreme attention to details and proficiency of training and continuous rising of qualifications for human resources.

Then, while the concept of sustainable tourism might be displayed in a truly wide number of elements, this particular research considers only primary yet crucial steps towards environmental sustainability: that is finding a cleaner, cheaper and, most importantly, renewable energy resource application in small aviation industry, which in turn corresponds to a sensitive air transportation sector and is an active role-playing segment in tourism industry. Further, by proposing cleaner alternative technological solutions and gradually eliminating the use of fossil fuels in a chosen industry, cumulative benefits in terms of continuous reduction in CO<sub>2</sub> emissions as well as relieving pressure from dependence on one energy resource are two of the few highly expected outcomes. Finally, introducing

more cost-effective solution for initial pilot training is another important step to assist the large air transport aviation industry to meet rapidly growing demand for air travel, especially in the Asia Pacific region.

### 8.3 Findings: Field Research 2

The second field research presented detailed investigation on current renewable energy solutions in the aviation industry and discussed how their potential usage might be implemented into Japan's environmental sustainability and tourism policies.

- What practical applications of renewable energy concept in aviation industry currently exist (industry analysis from global perspective)?

The research findings have shown that the most practical applications of renewable energy in aviation industry may be achieved through emphasizing transfer to electric propulsion within initial pilot training flight operation facilities in Japan. One of the key indicators of the serious pilot shortage in Japan has started to impact tourism flow already a year ago, when 2,128 scheduled flights operated by low cost carrier Peach Airlines to fly from May to October were cancelled, while Vanilla Air Inc. scrapped 154 flights in June. The overall number of flights has increased in Japan, and the budget airlines were unable to find a sufficient number of pilots to fill the void of those who left the companies or took sick leave (Asahi.com, 2015). According to the Ministry of Land, Infrastructure and Transport Japan will require another 9,000 qualified pilots by 2020, which is approximately 30% more than the country has at the moment. Pilot training costs are estimated to total between 15 million yen and 26 million yen (\$147,900 and \$256,300) (Asahi.com, 2015). Consequently, even if some of this initial tuition is covered with scholarships and governmental financing for domestic students, developing electric propulsion small aviation industry powered by alternative energy resources is crucial. This way, by cutting pilot training costs at least twice the industry can make a practical positive impact on reaching a timely solution for upcoming pilot shortage crisis in an environmentally sustainable manner.

- What are political, economic and technical challenges that restrain small aviation industry toward smooth sustainable transition?

**Safety** - in aviation industry has always been, is and hopefully remains to be the top priority in the future. Japan, as a target market for this research, is one of the top countries that have extremely high consciousness towards safety measures and accident precautions especially in transport. While Japan's airlines stands on 11<sup>th</sup> position according to airline safety ranking (Jacdecde, 2015), the safety index of 0.015 is very close to the top airlines from 0,006 to 0,014 (the lowest index to be 1,265). Therefore, with a high certainty it may be stated that any innovative actions regarding air transport in Japan will be considered with utmost safety precautions under applicable regulations.

**Aviation regulations and safety concerns** - generally, Federal Aviation Authority (FAA) does not tend to certify electrical aircraft yet, and the principal reason for that is an approach that electric propulsion must have equivalent level of safety when compared with the normal combustion airplane (Since Japan Civil Aviation Bureau (JCAB) and FAA share most of safety requirements and regulations, it is reasonable to deduce that precision of incident analysis conducted by National Transport Safety Board (NTSB) in US are trustworthy and may be in most cases relevant to Japan's requirements).

Through a detailed Failure Mode Effects Analysis (FMEA) and Fault Tree Analysis (FTA), NTSB derived list of facts about three Boeing 787 Dreamliner battery fire incidents. While some of the conclusions were relevant to large pressurized cabin aircrafts, particular findings are significantly important for constructing a pathway for electric propulsion in small aviation and its future airworthiness. After testing 15 packs of high capacity Boeing 787 batteries, NTSB came to the following (*Source: NTSB Presentation at CAFÉ Foundation EAS 2015 Symposium, California*):

- 1) The Li-Ion fault tree for transportation applications appears to be significantly more complex than in consumer applications – due the increased component count, higher voltage limits, higher power levels and greatly increased energy content.
- 2) Developing of highly accurate fuel gauging algorithms is clearly desirable but may require physics based cell models along with substantial cell characterization as is done in the automotive industry.
- 3) The Li-Ion thermal fault tree requires particular diligence due to flammable electrolyte (that explains an active research area in non-flammable electrolytes).

- 4) However, there do not appear to be any insurmountable faults – just the need for thorough engineering that address each of the fault pathways (combined with the healthy imagination for what can go wrong).

To conclude, other faults such as pilot errors, electric failure and software errors are always present; yet, there is a strong endeavor to believe that an improved electric propulsion technology should eventually transform aviation into its cleaner and environmentally more kindly version.

- How Japan's technological advancement, geographical positioning and current condition of aviation industry could be utilized to achieve effective transition toward more sustainable air transportation and environmentally friendly air-tourism practices?

**Technological Advancement** - Japan is an important global supplier of aviation electronics, engines, batteries as well as aircraft airframe and related parts and accessories. An Oxford Economics study revealed that aviation has a significant footprint in the Japanese economy, supporting 0.7% of GDP (JPY 3.135 trillion) and 0.7% of the Japanese workforce (429,000 jobs). Including aviation's contribution to tourism, the figures rise to 1.0% of GDP (JPY 4.501 trillion) and 1.0% of the workforce (620,000 jobs) (IATA 2015). Furthermore, the recent agreement between Panasonic and Tesla to build the Gigafactory to produce cells, modules and battery pack for Tesla's electric vehicles in US is yet another indicator of Japan's leadership in battery industry. According to the agreement, Panasonic will manufacture and supply cylindrical lithium-ion cells and invest in the associated equipment, machinery, and other manufacturing tools, while Tesla will take the cells and other components to assemble battery modules and packs. To meet the projected demand for cells, Tesla will continue to purchase battery cells produced in Panasonic's factories in Japan (Teslamotors.com, 2015). Continuous leading and innovation in battery technology (or energy storage itself) is by all means the most critical factor influencing the future vector of not only economically competitive but also environmentally sustainable operations of the small aviation industry powered by electric propulsion.

As for the medium and large size aircraft, certain fuel savings are feasible through adaptation of hybrid propulsion systems in the near future as stated by Airbus and Siemens, if those savings are originally based on aviation fuel price as a key factor. However, it is



author's strong belief that electric propulsion in large aviation has a potential global future only with the invention of safe nuclear energy storage capacitor or electric plasma accumulators. Yet, while not directly relevant to the small aviation sector, Japan is also leading in nuclear energy research and is an active participator in society of international plasma research institutes.

**Fuel resource dependence** - while covered in previous chapters, it is important to verify the crucial dependence on country's energy resources. "Japan ranked as the second largest net importer of fossil fuels in the world in 2012, trailing only China. This follows the Fukushima nuclear disaster in 2011, after which Japan suspended operations at all of its nuclear power plants. The loss of nuclear capacity resulted in a shift in Japan's energy mix toward oil and natural gas. Japan is now the third largest oil consumer and importer in the world behind the United States and China. Furthermore, it ranks as the world's largest importer of liquefied natural gas (LNG) and second largest importer of coal behind China. Japan has limited domestic energy resources, and the country meets less than 15% of its own total primary energy use from domestic sources" (Eia.gov 2015).

**Geographical positioning** - Japan consisting of several thousands of islands with Honsyu, Kyushyu, Hokkaido and Shikoku being the largest, is ideal for application of clean small air transportation solutions in tourism practices. While Japan has a well-developed network of roads and railways, extending it to remaining parts of the country will, apart from the requirement of enormous financial investment, cause extreme damage to the surrounding environment. On the other hand, development of small aviation does not require colossal infrastructure since small aircrafts are capable to land on considerably short runways and not necessarily paved ones, and sea adapted planes may also land on water, therefore, such version of light, green, fast and comfortable air transport might act as an another solution to avoid increasing traffic on roads and further promote tourism for the country's further located areas.

#### **8.4 Findings: Aviation Practices in United Nations Humanitarian Air Service**

The case analysis of UNHAS was chosen to emphasize critical issues in the global scale organization, where air charter operations directly impact volume of successful international rescue missions. In principal, the current condition of air charter agreement process is in its nature contradictions to peacekeeping ideology. The funds acquired from various donors

are, with immense disadvantage to UN budget, spent on satisfying the financial requirements of air charter operators. Since all UN air charter agreements are based on commercial terms, UN represents just another client with benefits (air operations for UN are under tax exemption policy) to any commercial air operator. While UN stands for the uppermost humanitarian and peacekeeping provider available today, highly commercialized operations and air charter leasing practices continues to place a heavy burden on the publicly criticized increasing budget spending. Saying that, since approximately 40% of air operations consist of aviation fuel, United Nations General Assembly should develop a strategy to seek for more efficient management of aviation alternatives.

## 8.5 Further Research Subjects

### 1) Air Transport Liberalization and Governance: Military Drones

A UAV or unmanned aerial vehicle (Figure 13), also called a drone, is a self-descriptive term commonly used to describe military and civil applications of the latest generations of pilotless aircraft. UAVs are defined as aircrafts without the onboard presence of human pilots, used to perform intelligence, surveillance, and reconnaissance missions. The technological objective of UAVs is to serve across the full range of missions cited previously. UAVs present several basic advantages compared to manned systems that include better maneuverability, lower cost, smaller radar signatures, longer endurance, and minor risk to crew (Lozano, 2013).

With the recent growth of drone applications, the further research vector will be oriented to study how innovative and highly efficient range and endurance solutions in certified military UAVs can be applied in small and medium aviation industries.

### 2) Realizing Sky Transit

“Realizing Sky Transit: Sustainable Mobility Freedom” introduced by Dr. Brien Seeley, CAFÉ Foundation, challenges the concept of environmentally friendly air taxis as a solution to rejuvenate general aviation by e-powered, VTOL/STOL (vertical takeoff landing / short takeoff landing) aircraft used on demand (see Figure 14 for VTOL/ STOL type of aircraft prototype). Based on a 6 minutes rule to conveniently reach the transportation loading point, the fully autonomous (no pilot) aircraft would be serviced by robotic battery swaps and fly on average 100 miles. According to Dr. Seeley it is, in fact, technically doable,

economically sustainable, and environmentally essential. Nevertheless, further research is needed on air-taxi conceptual design potential issues, opportunities, and practical application strategies.

**Figure 13: UAV, Military Drone**



*(Source: i.buffpost.com, 2015)*

**Figure 14: Joby Aviation S2 model (VTOL)**



*(Source: Jobyaviation.com, 2015)*

## Appendixes

### Appendix A (light aircraft / rotorcraft flight operators list in Japan)

社名 / URL	本社所在地
(株) アイ・エー・エス・エス <a href="http://www.iass.co.jp">www.iass.co.jp</a>	〒103-0025 東京都中央区日本橋茅場町 3-8-8 互恵ビル 4F
アイベックスアビエーション(株) <a href="http://www.ibexaviation.co.jp">www.ibexaviation.co.jp</a>	〒181-0015 東京都三鷹市大沢 5-21-12
朝日航空嫩(株) <a href="http://www.asahiair.com">www.asahiair.com</a>	〒581-0043 大阪府八尾市空港 2-12 八尾空港内
朝日航洋(株) <a href="http://www.aeroasahi.co.jp">www.aeroasahi.co.jp</a>	〒136-0082 東京都江東区新木場 4-7-41
東邦航空(株) <a href="http://www.tohoair.co.jp">www.tohoair.co.jp</a>	〒136-0082 東京都江東区木場 4-7-5, 東京ヘリポート内
(有)アドバンスドエアー <a href="http://www.addair.jp">www.addair.jp</a>	〒920-1341 石川県金沢市別所町ソ 76 番
アルファアビエーション <a href="http://alphaaviation.aero/ja">alphaaviation.aero/ja</a>	〒108-0073 東京都港区三田 3-5-21
社名 / URL	本社所在地
エクセル航空(株) <a href="http://www.excel-air.com">www.excel-air.com</a>	〒279-0032 千葉県浦安市千鳥 14
愛媛航空(株) <a href="http://www.air-ehime.co.jp">www.air-ehime.co.jp</a>	〒791-8042 愛媛県松山市南吉田町 松山空港内
岡山航空(株) <a href="http://www.air-oas.co.jp">www.air-oas.co.jp</a>	〒702-8024 岡山県岡山市南区浦安南町 673 岡南飛行場内
鹿児島国際航空(株) <a href="http://www.kagoshimainternationalaviation.iwasaki-group.com">www.kagoshimainternationalaviation.iwasaki-group.com</a>	〒892-8518 鹿児島県鹿児島市山下町 9-5
北日本航空(株) <a href="http://www.kita-nihon.com">www.kita-nihon.com</a>	〒025-0004 岩手県花巻市葛第 3 地割 183-1 花巻空港内
静岡エアコミュータ(株) <a href="http://www.sacc.co.jp">www.sacc.co.jp</a>	〒420-0902 静岡県静岡市葵区識訪 8-10 静岡ヘリポート
(株)ジャネット <a href="http://www.janet.co.jp">www.janet.co.jp</a>	〒400-0108 山梨県甲斐市宇津谷 445-1
新中央航空(株) <a href="http://www.central-air.co.jp">www.central-air.co.jp</a>	〒301-0806 茨城県竜ヶ崎市半田町 3177
水産航空(株) <a href="http://www.suisanair.co.jp">www.suisanair.co.jp</a>	〒182-0032 東京都調布市西町 290-3
セントラルヘリコプタ-サ-ビス(株) <a href="http://www.central-heli.com">www.central-heli.com</a>	愛知県西春日井郡豊山町大字豊場字林先 1-1 県営名古屋空港内
大阪航空(株) <a href="http://www.okk.jp">www.okk.jp</a>	〒581-0043 大阪府八尾市空港 2-12

## Appendix B (Interview Questionnaire during the Field Research)

Nr.	Questions	Details
<b>1.</b>	<b>Company overview, operational procedures and target customer</b>	
1.1	What is your type of business? List all that apply	Pilot training, charter, aerial services, business, medical, sport, agriculture, other
1.2	What are key elements in your company's operational procedures?	
1.3	Who are your target customers?	Provide percentage distribution, if applicable
<b>2.</b>	<b>Cost structure, resource supply, DOCs, available governmental subsidies</b>	
2.1	What is the cost structure of your company? Provide percentage distribution	Fuel, maintenance, administrative cost, human resources, other
2.2	How does resource supply chain work in your company?	Does any energy resource come from renewables?
2.3	What is your Direct Operation Cost?	
2.4	Do you receive any governmental support?	If yes, on what basis, how much it is and for what period of time?
<b>3.</b>	<b>Geographical positioning, main competitors, agreements with business and government organizations (if any)</b>	
3.1	What are advantages/disadvantages of your geographical location?	
3.2	Who are your main competitors?	Any foreign companies?
3.3	Do you have collaboration agreements with other business and government organizations?	If yes, provide details
<b>4.</b>	<b>Safety procedures, requirements and aviation regulations</b>	
	How would you describe your company's philosophy regarding safety?	List other than standard safety procedures, if applicable
	How aviation requirements imposed by government impact your company's type of operation?	
	Are there any current regulations that limit your company to expand or otherwise change type of operation?	List other limiting factors, if apply
<b>5.</b>	<b>Airway availability and congestion of the airspace</b>	
	What level of congestion would you prescribe to the airspace of your usual operation?	
	Has it changed for the last decade and if yes, at what extent?	Describe change tendencies from 2005, if applicable
	How efficient are your flights in terms of getting from point A to point B to complete the task?	
<b>6.</b>	<b>Track of environmental impact, renewable energy concept</b>	
	Do you track your company's environmental footprint?	
	Are there governmental regulations implying to follow environmentally friendly practices?	
	In your company, what energy percentage comes from renewables?	If no, list if there are intentions / future plans to do so

*Interview stakeholders: company top managers and/or chief pilots. Average time of each interview: 45min.*

## Appendix C (SolarStratos Data Sheet)

Wing span	25 m	Cruise speed	55 – 60 km/h
Wing surface	27 m <sup>2</sup>	Min. speed flaps retracted	45 km/h
No. of seats	2	Min. speed flaps extended	42 km/h
Empty weight	200 kg	Gust speed Vc	92 km/h
Max. weight	450 kg	VNE (Never exceed speed)	110 km/h
Max. battery capacity	30 kWh	Max. vertical climb speed	4 m/s (ground)
Max. battery weight	120 kg	Max. altitude	24 km
Max. Solar system power	5 kW (standard atmosphere), 8 kW (high altitude)	Max. edurance	Day – night mission possible with 90 kg pilot

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