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Bio-Fuel Alternatives in South African Airways (SAA) Operations - Is it an Effective Response to Vulnerability over Carbon Taxes and Penalty?

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The global aviation industry aims to achieve carbon neutral growth by 2020 and eventually reduce carbon dioxide (CO_2) emissions by 50% relative to 2005 levels by 2050 (ATAG, 2011). The International Air Transport Association (IATA) outlined a ‘‘four pillar’’ approach that includes technology, operations, infrastructure and economic measures to help reduce carbon dioxide emission (IATA, 2013). Technology has been seen as the most promising option for reducing emissions and includes improved engine technologies, aircraft design, new composite lightweight materials, and use of biofuels that have significantly lower lifecycle greenhouse gas (GHG) emissions than conventional fuel (IATA, 2013).

The South African government announced a strategy to develop a homegrown aviation biofuels industry to support the state-owned South African Airways (SAA). The announcement came in the wake of having to introduce a one to two euro carbon surcharge from the beginning of the year 2014 on passengers travelling to and from Europe to cover their European Union Emission Trading Scheme (EU ETS) costs (SAA, 2012; Air Transport World, 2014). The strategic plan has a goal of having 50% of SAA’s fuel uplifted at Johannesburg, at least, to be sustainable aviation fuel by 2023 (Greenair, 2012). South African Airways and The Department of Public Enterprises signed an MOU for collaboration with Boeing on biofuels, becoming the first airline in Africa to formalize an effort on this issue (SAA, 2012).

From an operational perspective, the question has always been whether the use of any form of alternate fuel like bio-fuel in South African Airways (SAA) operations will be an effective response to vulnerability over carbon taxes and penalty. In order to answer the research question, a quantitative research method was used to compare the carbon dioxide emission levels of South Africa Airways (SAA) fleet over the European routes using aviation Jet A-1 fuel and a hypothetical case scenario, if SAA had used a 25% ‘blend-in’ of Jet A-1/ Bio-Fuel. Finally, the paper highlighted some challenges that may be faced by SAA if a move is made to implement ‘blend-in’ bio-fuel for flights operations.

Literature Review

South African Airways

South African Airways (SAA) is the national flag carrier and largest airline of South Africa, with headquarters in Airways Park on the grounds of OR Tambo International Airport, Gauteng. The airline flies to 38 destinations worldwide from its hub at OR Tambo International Airport, using a fleet of 54 aircraft mostly made up of Airbus series 319, 320,330 and 340s. They also operate a Boeing 737-800 fleet and 737-300 freighter fleet. SAA was the first African airline to join the Star Alliance, and became the 18th member in the alliance. South African Airways flies to 37 international destinations in 26 countries in Africa, Europe, North America, South America, and Asia (SAA, 2015).

The European Union Emission Trading Scheme

The European Union Emission Trading Scheme (EU ETS) was initiated in 2005 and was initially restricted to static emission sources, such as power plants and cement factories. The inclusion of aviation was not authorized until 2008 (NBAA, 2014). The EU ETS, required airlines to actively participate for the first time in 2012 and capped the emissions of all flights to, from and within the 27 EU member states plus Norway, Iceland and Liechtenstein (with exceptions for some flights) (ATAG, 2011).

The EU ETS was established by involving both Annex I and non-Annex I countries. Miyoshi (2014) stated that under the Kyoto Protocol, ratified countries have different responsibilities and roles based on whether they are Annex I or non-Annex I countries. Miyoshi (2014) further suggested that a lot of non-Annex I countries have been concerned about the move by Annex I countries to a market-based mechanism (MBM) initiatives such as the EU ETS or levies in other regions.

The EU ETS functions using a system of emissions allowances, each allowance being equivalent to one ton of CO_2. In 2012, airline emissions were capped at 97% of the average annual emissions from 2004-2006, and airlines receive 85% of their proportionally-allocated allowances (based on 2010 emissions) for free. These aviation-specific 1-ton units are called EU Emissions Aviation Allowances (EUAA; Financial Times, 2014).

A US study by Malina et al. (2012) found out that the EU ETS had a relatively small impact on US airlines and aviation emissions and under the current allocation rules, US carriers′ profits may in fact increase due to windfall gains from free allowances. Derigs and Illing (2013) analysed the impact of the measure on air cargo airlines, with specific reference to how airlines can optimise their profits by adapting their network and schedules. In their findings, carbon dioxide (CO_2) reduction was shown to have a zero or marginal impact on cost increases, and small changes in the schedule of these cargo airlines may limit these. Zhang and Wei (2010) suggested that non-Annex countries like South Africa need to discover how to engage in and make use of the EU ETS, and the measure's future influence on their aviation sectors required further consideration.

Miyoshi (2014) investigated the impact of the EU ETS on an African airline compared to airlines in an Annex I country (South African Airways and British Airways). Miyoshi (2014) suggested that the impact of EU ETS on travel change and carbon cost change was very limited apart from the case of the high carbon price (€30 per tonne). Miyasho (2014) further suggested that the market carbon price was required to be high enough to allow high emitters to incur higher costs than lower emitters do. This should act as strong incentive for carriers to invest in the abatement measures by reducing emissions under the ETS.

Alternative Aviation Fuel Pathways

Renewable jet fuel processes currently certified for use in commercial aviation include fuel produced from a Hydro processed Esters and Fatty Acids (HEFA) process (also known as Hydro treated Renewable Jet fuel) and biomass-to-liquid (BTL) via a Fischer–Tropsch (ASTM, 2011) . Both these processes produce a product slate that includes diesel, jet fuel and other co-products (Pearlson, 2013). BTL production involves vaporizing a mixture of biomass and coal and converting the gas to synthetic liquid fuels through an F–T process. Fuel produced using an F–T process was certified for aviation by ASTM International Standard D7566 in September 2009 (ASTM, 2011). In South Africa, Sasol is providing SPK jet fuel using a Fischer-Tropsch technology and coal as a feedstock to airlines operating at O.R. Tambo International Airport (Sasol, 2011).

Under a HEFA process, renewable oil (vegetable oils, animal fat, waste grease and algae oil) is processed using hydrogen treatment (hydro processing) to yield a fuel in the distillation range of jet fuel, diesel and naphtha (Pearlson, 2013). On July 1, 2011, ASTM approved the jet fuel product slate of HEFA under alternative fuel specification D7566 (ASTM, 2011). HEFA fuel that meets this specification can be mixed with conventional jet fuel, up to a blend ratio of 50%.

HEFA is currently the leading process for producing renewable jet fuel and several airlines (including Aero México, Air China, Air France, Finnair, Iberia, KLM, Lufthansa and United) have performed commercial passenger flights with blends of up to 50% renewable fuel produced using this technology (IATA, 2012: KLM, 2014). In addition to the popularity of HEFA fuel in demonstration flights, Bauen et al. (2009)_suggested that as an estimate that the near-term uptake of biofuels will be greatest when oil crops are used in a HEFA process.

In June 2014, ASTM revised D7566, the aviation fuel standard concerning synthesized hydrocarbons, to include a type of biofuel called "Synthesized Iso-Paraffinic" (SIP) fuel from hydro processed fermented sugars. The SIP fuel is produced by the fermentation of biomass-derived sugars into Farnesene, followed by hydrotreatment and fractionation of Farnesene into Farnesane, and they may be blended at a maximum of 10% by volume with conventional jet fuel (ASTM, 2014).

Economic Challenges of the Commercial Use of Bio –fuel in Aviation

Large-scale deployment of aviation biofuels from pathways suited for aviation face significant challenges. These include high production costs and lack of integration of aviation biofuels into regulatory frameworks (Carriquiry et al., 2011; Carter et al., 2011). One of the much heralded challenges that faces operators who want to expand their 'green operations' may be the reality of the prohibitive cost and low economy of scale supply chain system of bio jet fuel (SQconsult, 2013).

The EU estimates that the cost to construct and secure production, including plant and supply chain of bio-fuel for commercial aviation production may be in the region of EUR3bn (Aviationeconomics, 2014). In addition to these, there is a further EUR3bn cost of the actual fuel above that of Jet Kerosene – equating to EUR1, 500/tonne more than the recent price for regular jet fuel (Aviationeconomics, 2014). Currently Jet A1 fuel costs below EUR700/tonne, so the EU estimate is that bio-jet will be almost three times that figure at over EUR2,200/tonne (Aviationeconomics, 2014).

The demand for bio jet fuel is small because of high prices and concerns about sustainability. For airlines, the fuel costs are approximately 30% of the total operational costs and in the US, the FAA's biofuel goal is met by commercial airlines and the military voluntarily purchasing a set quantity of renewable fuel each year, even though this fuel is more expensive than conventional jet fuel (Winchester et al., 2013). Due to the small margins and the highly competitive market that some airlines operate in, they may not be able to sustain their operations using biofuels, which is twice as high as fossil fuels on a large scale. Sustainability concerns make airlines extra prudent in their actions since bad publicity due to operational losses has the potential to damage them even further (ECOFYS, 2013).

The economics of biofuel seem to have been largely overlooked in the short-term feasibility debate. Even adding the carbon cost to the price of jet fuel, it is far more economically advantageous to burn regular fuel and pay the carbon penalty than to switch to biofuel (SQconsult, 2013). One tonne of jet emits just over three tonnes of carbon, carbon trades at less than EUR10/tonne, which means purchasing a tonne of jet kerosene will cost, say, EUR700 and cost a further EUR 25 to cover the carbon burden. Even with a trebling of the cost of carbon, it is significantly cheaper than the projected EUR2, 200/tonne for bio-jet fuel (Aviationeconomics, 2014).

South African Airways Green Policy

South African Airways envisages to become the "most sustainable airline in the world" and has plans to scale up its use of biofuels for its flights to 20-million litres in 2017, before reaching 400-million litres by 2023 (SAA, 2012). Some of the benefits of SAA's shift to replacing fossil fuels with aviation biofuels include reduced operational costs and stability in fuel price planning, purchasing and foreign exchange.

A tobacco feed stock variant called Solaris which is under development to produce bio-jet fuel has the ability to reduce CO_2 emissions, bring socioeconomic value to local farmers, create jobs and lower the carbon footprint and fuel costs of SAA, the latter of which contributed between 39% and 41% of the State-owned airline's total operating costs (Engineeringnews, 2014). The nicotine- and GMO-free Solaris crop, which was developed and patented by Italy-based research and development company Sunchem Holding, would now be scaled-up across other regions in South Africa and potentially beyond into Africa.

The Solaris project envisages 250 000 ha by 2025, which would result in the production of 700 000 t of bio-jet fuel. The project is expected to create 250 000 jobs and shave-off 1558 Kiloton of CO_2 emissions, thus ensuring a sustainable, environment-friendly aviation industry (Engineeringnews, 2014).

Research Objective

In this study, a comparative analysis of the South African Airways current fleet that used conventional aviation jet fuel and the same fleet if it had used a 25% bio-fuel 'drop in' mixture of conventional jet fuel and bio-fuel over the European routes within the first quarter of the 2014 flying year (FY 14) was conducted. In order to answer the research question, a comparison of carbon dioxide emission using Jet A-1 fuel and a hypothetical 25% bio-fuel/JetA-1 'blend in' was done to find out if there will be any significant benefits for South African Airways in their flight operations to their European destinations.

Research Questions

To guide this study, the following research questions were utilized:

1. Will there be any significant differences in terms of carbon dioxide emission between the use of conventional jet A1 fuel and the bio-fuel alternative in South African Airways operational flights to Europe in the first quarter of FY14?

2. Will there be any significant differences in terms of the EU ETS per stage length in the South African Airways flight operations to Europe using conventional jet A1 fuel and bio-fuel alternative in the first quarter of FY14?

Method

The study utilized archived operational data in terms of the flight scheduled, aircraft type, total time enroute, route stage length, passenger estimates from South African Airways flight operations department and the company website (SAA, 2015). The performance data (burn rate, route stage length, total time enroute) for the hypothetical case scenario was estimated from another airline that conducted flights using 25% bio-fuel ‘blend-in’ over similar range with similar aircraft type (IATA, 2012; KLM, 2014; Young, 2014). The operational data was collated for the first quarter of the winter and spring schedule for flights from their main hub Oliver Tambo International Airport (FAOR) formerly Johannesburg International Airport (JNB) to four European destinations. The destinations were London Heathrow (LHR), Frankfurt Main, Munich International (MUC) and Zurich International (ZRH).

The stage lengths, Estimated Block Time (total time of flight from chocks out to chocks in) were obtained from SAA flight operations. The amount of fuel burnt for the stage length and finally the amount of carbon dioxide emitted over the entire period of the flight was estimated for the various aircraft in SAA fleet used for the flights from the CORINAIRE charts (EMEP, 2014). The EMEP/CORINAIR Emission Inventory Guidebook 2 (EIG) is the bases of commercial aviation fuel burn and emission information (EMEP, 2014). The Guidebook includes an accompanying workbook, which details fuel burn and emissions associated with discrete mission distances for 44 equivalent aircraft types.

In order to implement the methodology, the database used by ICAO takes the fuel burn to distance flown data provided by CORINAIR and extends some aircraft ranges by extrapolation using a linear regression (EMEP, 2014). This approach was chosen since the fuel consumption curve approaches a linear relationship to distance when considering medium and long haul flights.

Most air carriers have detailed information in regards to their fuel consumption and fuel efficiency, however, this information is not publicly available (EMEP, 2014). The ICAO methodology employs a distance-based approach to estimate an individual's aviation emissions using data currently available on a range of aircraft types. At present, it was not possible to identify any suitable public alternative data source, making CORINAIR the best publicly available data source for the purpose of the ICAO methodology (ICAO, 2014).

All the relevant data was tabulated using SPSS® and analyzed for descriptive statistics. The total surcharge per stage length and based on the amount of carbon dioxide emitted during the flight was calculated based on the EU ETS guideline of an average value of €8/ton of carbon dioxide emitted (Financial Times, 2014). The mean emission of CO_2 per ton burn of conventional jetA1 was compared with the mean emission of CO_2 per ton burn of the 25% bio fuel 'blend –in'.

An independent *t*–test is an inferential statistical test that determines whether there is a statistically significant difference between the means in two unrelated groups. This statistical test was conducted to find out if there was any significant differences in emissions between the two categorical flight operational groups of fleet that had 'YES or No' biofuel blend-in. The second *t*-test of means analysis compared the EU ETS per conventional jet A1 fuel and 25 % 'blend-in' to find any form of statistical significance. Figure 1 shows the conceptual pathway for the estimation of the flowchart used in the CORINAIRE.

In order to calculate the total amount of carbon dioxide emitted over the stage length by the SAA fleet, the EMEP/ICAO Formula was used:

Total amount of CO_2 produced = 3.157 x total tons of aviation fuel burnt over the entire stage length of the flight. Note: ***3.157*** = *constant representing the number of tons of CO_2 produced by burning a ton of aviation fuel* (ICAO, 2014).

All the variables were tabulated and stored in an SPSS®, where a descriptive statistics and *t*-test of means was conducted to compare the means of both the total emission of carbon dioxide per stage length and EU ETS per stage length for the SAA fleet on the EU route. The importance of the test was to find out if there were any significant statistical differences in the means using conventional jet A1 fuel and using a 'drop-in' blend of 25% bio-fuel alternate for the trips.

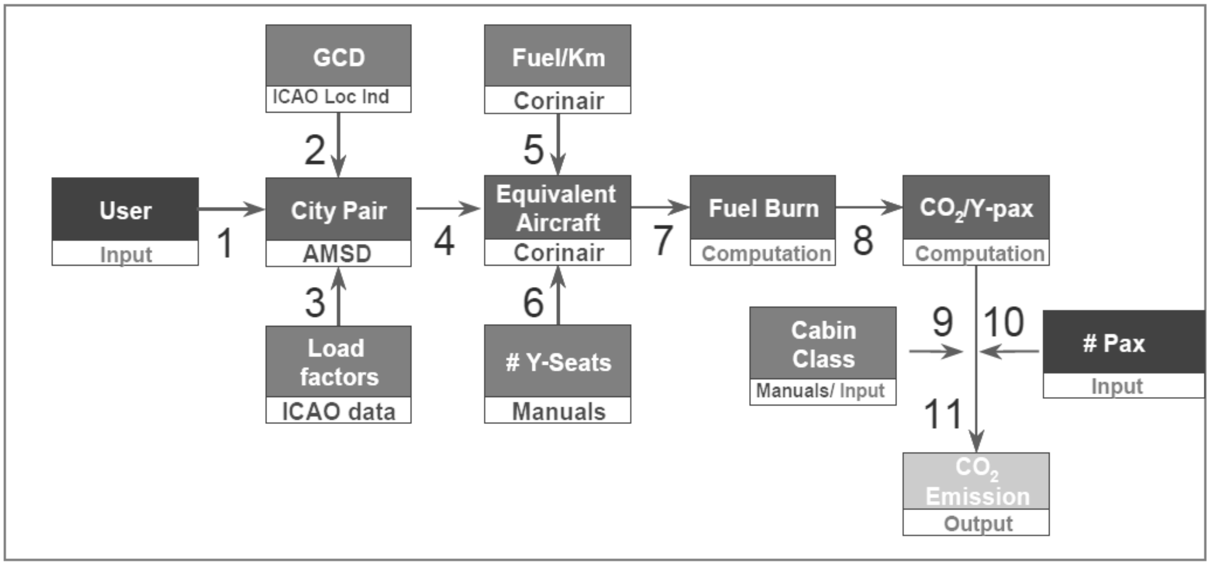

Figure 1. Flowchart of methodology used by ICAO /CORINAIR to determine the total emission of CO_2 produced by burning a ton of aviation fuel (ICAO, 2014)

Results

Question 1.Will there be any significant differences in terms of carbon dioxide emission between the use of conventional jet A1 fuel and the bio-fuel alternative in South African Airways operational flights to Europe in the first quarter of FY14?

The results from the analysis showed that there existed statistically significant differences in the carbon dioxide emission from the Jet A1 used in the flight operations to EU countries by SAA as compared to the 25% alternative bio-fuel blend. There may have been a decrease in the carbon dioxide emission in flights to EU countries within the study period if SAA had used the 25 % bio-fuel blend as compared to the conventional Jet A1 fuel. The mean carbon dioxide emission for the Jet A1 conventional fuel was (M= 211,729.91, SD = 39,306.29) as compared to the 25% ‘blend-in’ bio-fuel (M= 160,913.78, SD= 30,521.59. There was a statistical significance for the t-test for equality of means t (1149.65) = 25.25, $p <$ .001. The difference in emission per fleet type is shown in Figure 2 and per route is shown in Figure 3.

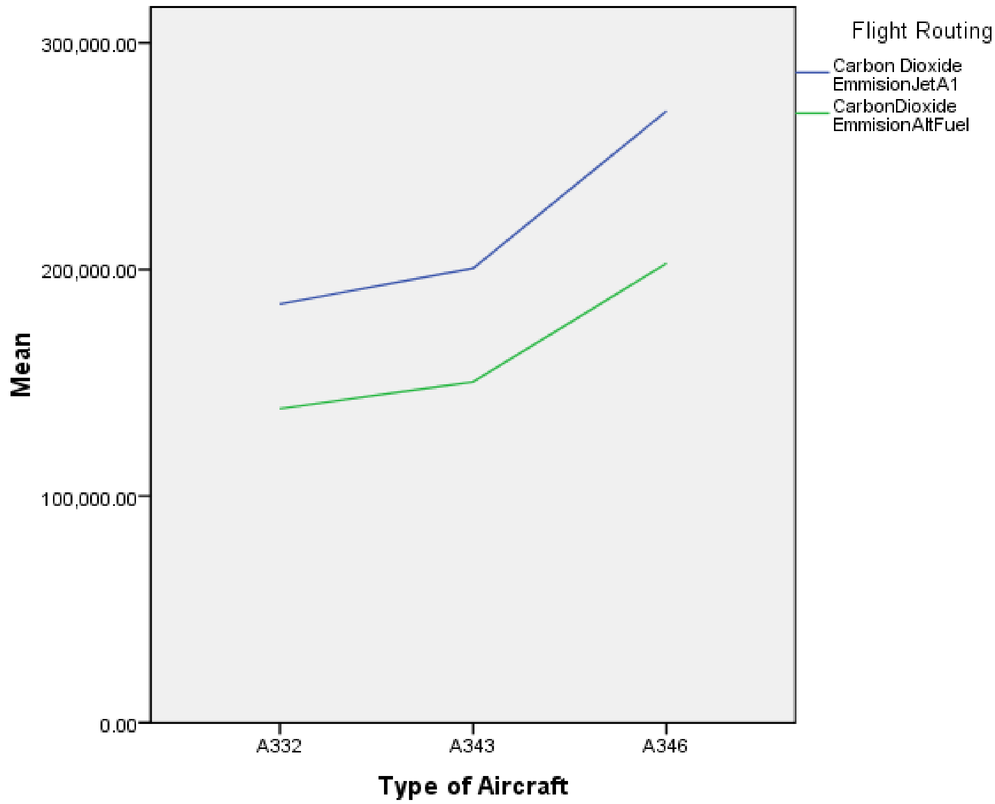

Figure 2. A plot of the mean CO_2 emission of SAA per fleet for flights to Europe using Jet A1 and Alternate Fuel blend.

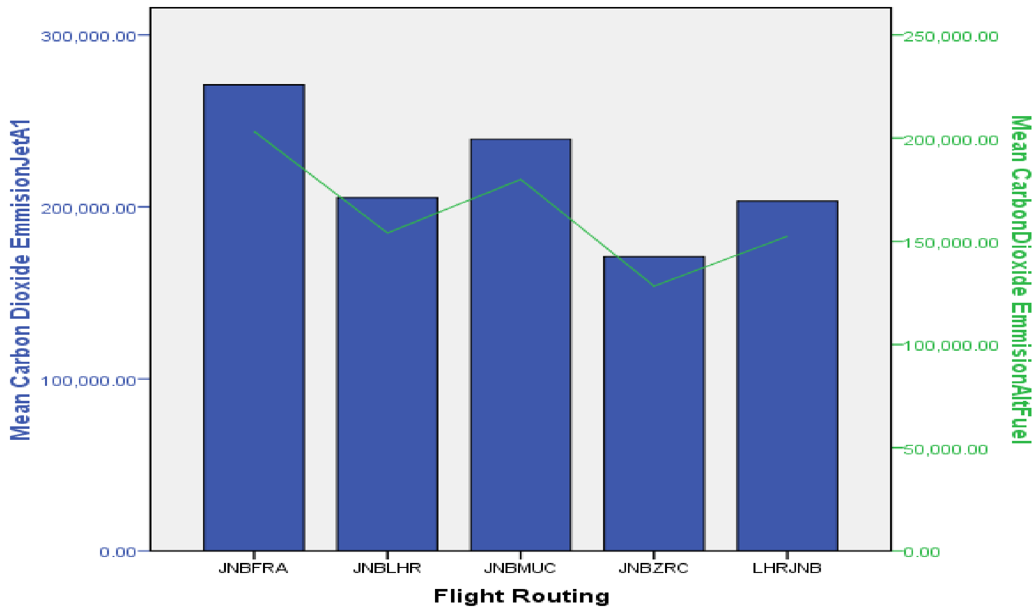

Figure 3. Mean Carbon Dioxide per SAA EU Flight Routings in Q1 FY14.

Question 2. Will there be any significant differences in terms of the EU ETS per stage length in the South African Airways flight operations to Europe using conventional jet A1 fuel and bio-fuel alternative in the first quarter of FY14?

In order to answer the second research question, an independent *t*-test was conducted on the EU ETS that would have been charged on SAA for using the two types of fuel in the operational flights. The results from Table 1 show that there was a decrease in the EU ETS for flights to EU countries within the study period when using the 25 % bio-fuel blend as compared to the conventional Jet A1 fuel. The mean EU ETS for the 25% ‘blend-in’ bio-fuel was (*M*= 1286.90, *SD* = 244.19) as compared to the JetA1 (*M*= 1715.90, *SD*= 325.59).

Table 1
Mean EU ETS per flight for SAA flight Operations into EU both Jet A1 and Alternate Bio-Blended Fuel.

	Was biofuel blended?	*n*	Mean (1000)	Std. Deviation (1000)	Std. Error Mean
EUETS	Yes	612	1.2869	.24419	.00987
	No	612	1.7159	.32559	.01316

The results showed that the Levene's Test for homogeneity of variance was significant, which showed that the data was not significantly normally distributed. The section of equal variances not assumed was used for the *t* statistics. There was a statistical significance for the *t*-test for equality of means t (1133.16) = -26.08, $p < .001$. The practical implication was that there existed statistically significant differences in the EU ETS using Jet A1 used in the flight operations to EU countries by SAA as compared to the EU ETS using the 25% alternative bio-fuel blend. The reduction in the EU ETS using the 25% alternative bio-fuel blend as compared to the Jet A1 fuel across the fleet type are shown in Figure 4 and per route in Figure 5. The results suggested that higher percentages of bio-fuel 'blend-in' for the flights might have resulted in lower emissions and subsequently lower EU ETS.

Example Analysis of Using Jet A1 and 25 % Bio-fuel 'blend-in' per flight to EU

Mean Jet A1 fuel burnt across entire SAA fleet per flight = 67.63 tons

Mean 25 % biofuel blend in burnt across entire SAA fleet per flight = 16.90 tons

Mean 75 % Jet A1 used for mix = 50.72 tons.

1 ton of Jet A1 =3.785 L (1 USG) * 0.0008075 metric tons/L (density) = 327.15 USG (Convertunits.com, n.d.)

Price of Jet A1 as at March 2015 in Johannesburg South Africa = 1.71 USD / USG (Aeroportos.weebly.com, n.d.).

Cost of 100% Jet A1 burnt per stage length = 67.63 * 327.15 * 1.71 = 37,834 USD

Cost of 75% Jet A1 burnt per stage length = 50.72* 327.15* 1.71 = 28,372 USD

Cost of 25% Bio jet fuel blend in burnt per stage length = 16.90*327.15* 1.71 * 3 = 28,363 USD

Total Bio fuel Jet A1 blend in = 28,372 + 28,363 = 56,735 USD

Differences in cost between 100% Jet A1 and biofuel blend in = 56,735-37,834 = **18,901 USD**

Total mean surcharge of EUETS for Jet A1 burnt = 1716 euros *1.08 = 1854 USD

Total mean surcharge of EU ETS for bio fuel blend in burnt = 1287 euros * 1.08 = 1390 USD

Differences in mean surcharges of EU ETS = 1854 -1390 = **464 USD per trip.**

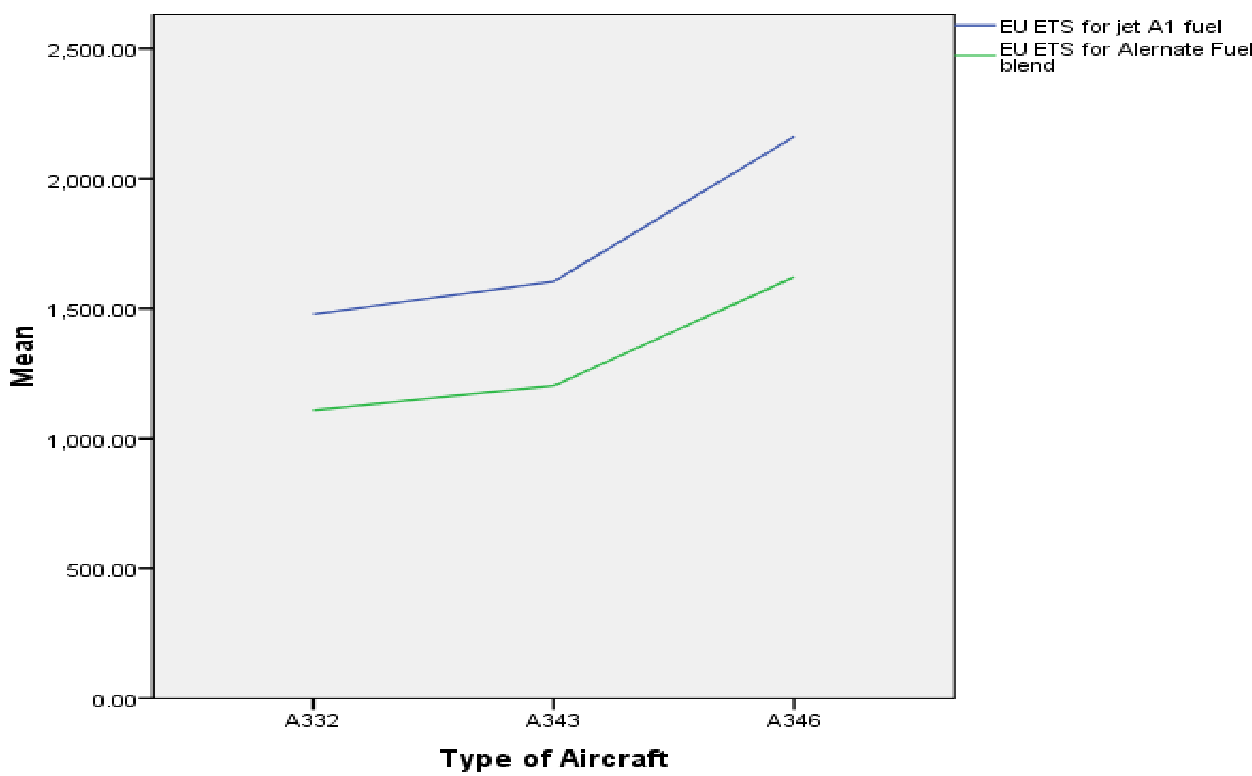

Figure 4. A linear plot of the mean EUETS charged SAA for flights to Europe using Jet A1 and Alternate Fuel blend.

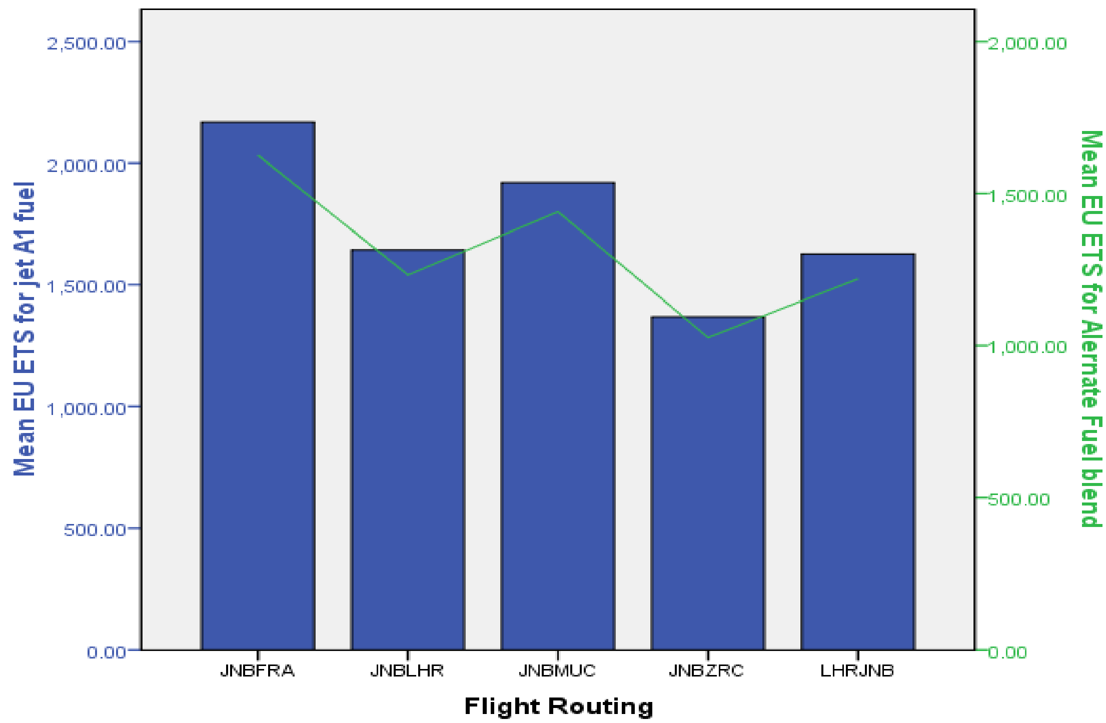

Figure 5. A Dual Axis plot of the mean EUETS charged SAA for flights to Europe using Jet A1 and Alternate Fuel blend.

Discussion and Conclusion

The results showed that South African Airways stands to benefit substantially in terms of reduction in carbon emissions and EU ETS by introducing and using bio-fuel blend-in and overall bio-fuel alternates as compared to conventional fossil fuel (Jet A1) across the broad spectrum of their operations. The results is in tandem with preliminary trials by other leading world class airlines like KLM,Air France, Air Canada and others that have substantially cut down on their carbon foot prints through the adoption and use of blended bio-fuel alternates (Young, 2014). The other advantages for the travelling public can be the subsequent reduction in 'green surcharges' that has been passed down to the passenger as airlines get taxed for excessive carbon emissions and exceeding carbon quota in flights to EU countries.

However it may be operationally profitable for SAA to use 100% Jet A1 and pay the EU ETS surcharge, if they exceed their allowable cap rather than use the bio fuel "blend-in fuel", due to the high cost of blended fuel, as compared to the EU surcharges for carbon emission. This may be one of the present challenge airlines ready to implement bio fuel in their flight operations face. These numbers suggest that the emissions offsetting scheme proposed by IATA is currently more cost-effective than using biofuels to abate aviation emissions and prevent surcharges. However, biofuels may play a future role as the cost of these technologies decrease and global demand for emissions reduction credits increase the price of offsets.

In order to overcome the supply chain challenge of having a sustainable supply of bio-fuel for flight operations, it is reassuring that Boeing and South African Airways (SAA) are extending the collaboration on a sustainable bio-fuel production and supply chain to include the Roundtable on Sustainable Biomaterials (RSB). The three partners have announced an initiative to help small hold farmers in the region grow crops to produce sustainable fuels. SAA has a target of having 50 per cent of its fuel uplifted at Johannesburg to be made up of sustainable jet fuel by 2023 (RSB, 2014).

The sustainable biofuel supply chains may also enhances a viable economic opportunity for local agriculture and energy production. A pragmatic example can be the Southern Africa Green Initiative, which has seen Boeing and RSB working together with stakeholders to create pilot programmes to build knowledge, and skills among groups of farmers who want to certify their feedstocks as sustainable. The partners will also help farmers with small plots of land gain access to markets for sustainable biofuels and biomaterials. In the long term, they expect more farmers to tap into a demand for biofuel feed stocks that provide socio-economic value to local communities without adverse impact on food supplies, fresh water or land use. (RSB, 2014)

South African Airways may need to expedite their joint production of bio-fuel in order to ensure a seamless supply chain that will reduce the production cost of the bio fuel needed for the blend-in for flight operations. Such a strategic measure may significantly enhance their 'green operations' and reduce their carbon footprint and set them on the goal of meeting the objectives of the carbon neutrality of 2020. In terms of the reduction of carbon dioxide emission, there may be quantifiable and tangible metrics to show, but as to the overall effect on the operational cost taking into consideration the present cost of bio-fuel and Jet A1, there may be substantial challenges.

This study looked at only a small data set (Quarter 1) for the entire FY14 of SAA and recommend that further studies consider operational data with a wider data set spanning more than a year. It would be insightful to get actual operational data from SAA on bio-fuel operations and assess emission/EUETS trends over the same route with a newer fuel-efficient fleet. Future studies may look at long term economic, environmental and operational challenges that other airlines from developing countries in Africa, will be faced with, should they decide to use biofuel in their flight operations. These challenges will have to be analysed within the framework of the real and present competition, they face from top-tier airlines from Europe.

References

Aeroportos.weebly.com. (n.d.). Fuel prices. Retrieved from http://aeroportos.weebly.com/fuel-prices.html#.VQ-fCvnF-So

Air Transport World. (2014). *Boeing-South African Airways expand biofuel initiative.* Retrieved from http://atwonline.com/eco-aviation/boeing-south-african-airways-expand-biofuel-initiative

American Society for Testing and Materials (2011). ASTM *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, Designation D7566-12a.* West Conshohocken, PA: ASTM International. Retrieved from http://enterprise.astm.org/filtrexx40.cgi?±REDLINE_PAGES/D7566.htm

American Society for Testing and Materials (2014). ASTM *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. Designation D7566-14c*, West Conshohocken, PA: Author. Retrieved from http://www.astm.org/Standards/D7566.htm doi:10.1520/D7566-14C

Air Transport Action Group (ATAG). (2011). *Beginners guide to aviation biofuel 2 ed.* Geneva: Air Transport Action Group. Retrieved from http://www.atag.org/our-activities/sustainable-aviation-biofuels.html

Aviationeconomics. (2014, April 14). *News.* Retrieved from http://www.aviationeconomics.com/NewsItem.aspx?title=The-Commercial-Use-of-Biofuels-in-Aviation

Bauen, A. H. (2009). *Review of the Potential for Biofuels in Aviation. Final Report Prepared for the Committee on, Climate Change.* Geneva, Switzerland.: E4tech. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=E296A64BF3E834001B828 1496DA49C7D?doi=10.1.1.170.8750&rep=rep1&type=pdf doi:10.1.1.170.8750

Carriquiry, M. A., Du, X., Timilsina, G. R. (2011). Second generation biofuels. *Economics and policies Energy Policy*, 39, 4222–4234.

Carter, N., Stratton, R., Bredehoeft, M., Hileman, J. (2011) *Energy and environmental viability of select alternative jet fuel pathways*. 47th AIAA Joint Propulsion Conference, San Diego, CA.

Convertunits.com. (n.d.). *Converting tons to U.S. gallons*. Retrieved from http://www.convertunits.com/forum/message/614/Re-Converting-tons-to US-gallons

ECOFYS. (2013). *Biofuels for aviation.* Retrieved from http://www.ecofys.com/files/files/ecofys-2013-biofuels-for-aviation.pdf

Engineeringnews. (2014). *SAA to test biofuel flight next year*. Retrieved from : http://www.engineeringnews.co.za/article/saa-to-test-biofuel-flight-next-year-2014-12-09

European Monitoring Evaluation Program (EMEP). (2014). *EMEP EEA guidebook.* Retrieved from www.eea.europa.eu: http://www.eea.europa.eu/publications/emep-eea-guidebook-2014/

Financial Times. (2014, October 14). *CMS.* Retrieved from http://www.ft.com/cms/s/0/23d2b622-4fce-11e4-a0a4-00144feab7de.html#ixzz3RJPJ2cIp

Greenair. (2012). *South Africa looks to develop aviation biofuels supply chain in response to vulnerability over carbon taxes and penalties.* Retrieved from http://www.greenaironline.com/news.php?viewStory=1567

Greenair. (2015). *Finnair and SAA first to reach the top level in IATA's airline environmental assessment programme.* Retrieved from http://www.greenaironline.com/news.php?viewStory=2028

International Air Transport Association. (2013). *IATA 2013 report on alternative fuels.* Montreal: Author. Retrieved from http://www.iata.org/publications/documents/2013-report-alternative-fuels.pdf

International Civil Aviation Organization. (2014). *ICAO environmental report* Montreal: Author. Retrieved from http://cfapp.icao.int/Environmental-Report-2013/#124

KLM. (2014). *KLM biofuel flight*. Retrieved (02/22/15) from : http://news.klm.com/klm-biofuelflight-aua-bon/

Malina, R., McConnachie, D., Winchester, N., Wollersheim, C., Paltsev, S.,Waitz, I. A.(2012).The impact of the European Union emissions trading scheme on U.S. aviation , *Journal of Air Transportation Management*, *19*, 36–41.

Miyoshi,C. (2014). Assessing the equity impact of the European Union emission trading scheme on an African airline, *Transport Policy*, *33*(C), 56-64. doi:10.1016/j.tranpol.2014.02.010

National Business Aircraft Association. (2014). *Environment: EU.* Retrieved from : http://www.nbaa.org/ops/environment/eu-ets/

Pearlson, M. (2013). A techno-economic review of hydroprocessed renewable esters and fatty acids for jet fuel production. *Biofuel, Bioproducts and Biorefining, 7(1)*, 89-96.

RSB. (2014). *Smallholder program in Africa.*. Retrieved from http://rsb.org/activities-and-projects/smallholder-program-in-africa/

Sasol. (2011, February 09). *Facts.* Retrieved from http://www.sasol.com/sasol_internet/downloads/11029_Sasol_Facts_2011_1309786765289.pdf

South African Airways. (2012). *Flysaa.com/News*. Retrieved from http://www.flysaa.com/za/en/flyingSAA/News/SAA-to-raise-surcharge-to-comply-with-EU-Emissions-Trading-Scheme.html

South African Airways. (2015). *Plan my trip*. Retrieved from http://www.flysaa.com/za/en/planmytrip/schedulesroutes/flight_schedules.html

SQconsult. (2013). *Content.*. Retrieved from http://www.sqconsult.com/content/newsletter_html/mrt_14_SQ_Consult_Bringing_biojet_fuels_to_the_market.html

Winchester, N. M. (2013). Economic and emissions impacts of renewable fuel goals for aviation in the US. *Transportation Research Part A, 58*, 116-128. Retrieved from http://www.researchgate.net/publication/259138966_Economic_and_emissions_impacts_of_renewable_fuel_goals_for_aviation_in_the_US doi:10.1016/j.tra.2013.10.001.

Winchester, N., Malina, R., Staples, M. D., Barrett, R. S. H. (2015).The impact of advanced biofuels on aviation emissions and operations in the U.S. *Energy Economics*, *49*, 482-491. doi:10.1016/j.eneco.2015.03.024

Young, N. (2014). The future of biofuels: U.S. (and Global) airlines & aviation alternative fuels. *EIA Conference Presentations*. San Antonio,TX: EIA. Retrieved from http://www.eia.gov/conference/2014/pdf/presentations/young.pdf

Zhang, Y., Wei, Y. (2010). An overview of current research on EU ETS: evidence from its operating mechanism and economic effect. *Applied Energy*, 87, 1804–1814.