Public attitudes to biofuel use in aviation: Evidence from an emerging tourist market

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Aviation generates substantial carbon footprint which is projected to increase due to the continuous growth in international tourism, especially in the emerging markets. This carbon footprint should be mitigated to bring the tourism industry towards its sustainability goals. Within a portfolio of prospective carbon mitigation measures, biofuels represent a technological innovation which holds substantial potential to reduce the carbon significance of aviation. The success of technological innovations often depends on public opinion. The role of public opinion is particularly relevant in the aviation context, where safety considerations of technological innovations may determine consumer choice. Focusing on Poland, an emerging tourist market in Europe, this study explored public opinion on biofuel use in aviation. It found that public understanding of the perspectives of aviation biofuel technology, including its safety, is limited and needs to be reinforced. Public distrust in the national institutions of power and the industry sector representatives in Poland calls for educational and public awareness-raising campaigns to be delivered by the 'third sector' organisations.

Keywords

Climate change, carbon footprint, aviation, biofuel technology, public opinion, Poland

Highlights

- Biofuel technology can reduce the carbon footprint of aviation
- Public opinion on a new technology can determine the speed of its market penetration
- We investigate public opinion on aviation biofuel technology in Poland
- Public understanding of the implications of biofuel use in aviation is limited
- Public knowledge should be reinforced by the ‘third sector’ organisations

1. Introduction

The greenhouse gas (GHG) emissions from aviation have been growing steadily in recent decades and this trend is set to continue (Peeters and Eijgelaar 2014). This is primarily due to the rise in international tourism, where air travel represents the mainstay of tourist demand for transportation between the source and host regions (Scott *et al.* 2010). Being a major driver of air travel, tourism makes a substantial economic contribution to the global and national economies (UNWTO 2015). Geographically, 'traditional' or 'established' destinations in Western Europe and North America are forecast to retain their strategic importance in terms of tourist demand. Concurrently, the rapid acceleration of tourist flows is envisaged in so-called 'emerging' destinations, such as those in East-Central Europe and Asia (UNWTO 2015). Given that tourism growth correlates with air travel, these 'new' tourist markets are likely to contribute significantly to the continued rise of the GHG emissions from aviation (Meng *et al.* 2016).

The problem of the disproportionally high carbon impacts associated with flying has been recognised (Scott *et al.* 2016) and a number of policy-making and managerial interventions have been designed to minimise the carbon significance of air travel. To maximise the positive outcome, these interventions have targeted the aviation industry and its customers, thus embracing both the supply and demand sides (Schwanen *et al.* 2011). They have employed a range of voluntary and mandatory instruments to facilitate more carbon-benign business operations and to architect more responsible consumer choice (Gössling *et al.* 2009).

The interventions have been applied with varying degrees of success (Gössling *et al.* 2007). There is evidence to suggest that voluntary changes in consumer behaviour cannot be considered a viable, stand-alone tool for reducing the carbon footprint of air travel in a short-term perspective (McKercher *et al.* 2009). Consumers fail to link flying to carbon impacts (Hares *et al.* 2010). Furthermore, despite growing public environmental awareness, the substantial GHG emissions from aviation do not yet represent a sufficient determinant for tourists to change their travel behaviour towards less carbon-intense holidaying patterns (Cohen and Higham 2011). This underlines the importance of other instruments, such as technological advancements, regulatory measures and financial (dis)incentives,

as means of facilitating progress of the air transport sector towards the goal of environmental sustainability (Kivits *et al.* 2010). Although technological advancements in aviation do not always deliver their aspirational carbon reduction targets (Peeters *et al.* 2016), when combined with other mitigation approaches, most notably with voluntary behavioural changes, they can bring about substantial carbon savings (Gössling *et al.* 2009).

Among technological innovations developed to reduce the GHG emissions from air travel, biofuels play a substantial role. They are both operationally feasible and hold recognised potential to effectively decarbonise the global transportation industry, including its sector of aviation (Krammer *et al.* 2013). Although, in short-term perspective (i.e. before 2020), biofuels cannot compete with traditional, fossil based jet fuels (Kousoulidou and Lonza 2016), oil price volatility and increasing public and political environmental pressures on the industry drive the long-term biofuel adoption in aviation (Gegg *et al*. 2014).

Biofuel technology has a number of limitations. These are attributed to such issues as feedstock availability; production costs; land use changes; the 'food versus fuel' dilemma; lifecycle carbon footprint; and logistics of continuous supply and distribution (see Hari *et al.* 2015 for a detailed overview). Despite their drawbacks, biofuels hold substantial potential to be employed in aviation, especially given the advent of advanced generation biofuels (Kivits *et al.* 2010). Subject to steady demand, political support and balanced business models, these can reduce costs and address some of the other challenges of biofuel production, thus making biofuels a feasible alternative to conventional jet fuel (Nair and Paulose 2014).

When applied in the context of air transport, biofuel technology has been investigated by a number of aviation operators who view it as an opportunity to fulfil the intensifying environmental regulations, address the risen shareholder expectations on the sustainability performance of business operations, and create a positive corporate image (Hari *et al.* 2015). As a result, since 2008, the different blends of biofuels and conventional aviation fuel have been tested by the airlines worldwide (see Enviro Aero 2017 for a regularly updated inventory of the biofuel-driven flights). With all trials being successful, the industry experts agree that aviation will become a considerable market for

biofuels in the coming years (Chiaramonti *et al.* 2014). Furthermore, with increased production supported by policy-makers, industry professionals and consumers, biofuels have potential to become a financially-feasible alternative to conventional fuels in longer term even though direct cost benefit comparisons are difficult to derive due to the lack of published cost data on biofuels (Sims *et al.* 2010). While the aviation industry has made considerable progress to-date in terms of feasibility research and the trial operational adoption of biofuel technology, little is known about public awareness of these industry's efforts. While public knowledge on, and public attitudes to, biofuel *in general* represent a sufficiently well-established object of scientific scrutiny (see, for example, Sawanidou *et al.* 2010), biofuel research has primarily been concerned with the use of biofuel technology in the road transport sector. Literature search returns scant results when looking for studies on aviation biofuels alongside public knowledge of and attitudes to their broader adoption. There are a number of reasons for why public perception of aviation biofuels should be better understood. First, aviation biofuels are a relatively new, and yet rapidly developing, instrument of carbon impact mitigation (Noh *et al.* 2016). Evidence suggests that the speed of the market rollout and the overall adoption rates of a new technology are often dependant on the level of public knowledge and on the degree of public trust in it (Assefa and Frostell 2007; Clothier *et al.* 2015; Schulte *et al.* 2004). These variables are instrumental in enhancing the levels of social acceptance of a new technology, especially in the context of renewable energy generation (Ellabban and Abu-Rub 2016; Ponce *et al.* 2016; Wüstenhagen *et al.* 2007), which signifies the importance of their better understanding. Second, while biofuel safety is a paramount issue which has been meticulously monitored by aviation regulators, industry experts and 'third sector' representatives, marketing research posits that consumers may be reluctant to accept the innovation interventions in the established and mature market environments, such as flying, due to the general fear and anxiety of the 'new' (Meuter *et al.* 2003). This reluctance, multiplied by the issue of safety, which has traditionally been a determinant of the public preparedness to fly (Hall 2002), has to be minimised to ensure success of those aviation business ventures that have chosen to implement biofuel technology. Given that airlines are particularly vulnerable to public opinion (Hamelinck *et al.* 2013), they should introduce innovations with care, and public opinions on a new technology, such as biofuels, should be diligently examined prior to its

large-scale deployment (Greiner and Franza 2003). Lastly, biofuels as a carbon footprint abatement tool are often seen as means to showcase their adopters' good global citizenship, which holds true for the sector of aviation (Kowal and Henderson 2015). However, such publicity can only become effective when consumers embrace the progress made by the industry and understand its potential (Hamelinck *et al.* 2013). The literature indicates that poor public knowledge on a new technological advancement alongside the advantages it has set to deliver can hamper its rapid market penetration; it can further confuse customers and detrimentally affect their purchasing decisions (Wegener and Kelly 2008).

This paper contributes to knowledge by exploring public attitudes to the use of biofuels in aviation. It identifies the levels of public knowledge on the application of biofuel technology in the sector of air travel alongside the carbon mitigation benefits it offers. The issue of biofuel safety is also investigated given the relative 'novelty' of aviation biofuels and the important role played by safety considerations in consumer decision-making to fly. The project concentrates on Poland with its rapid growth in inbound and outbound air travel market (Burrell 2011), which signifies the rising contribution made by this country to the carbon intensity of aviation, globally and in Europe. The focus on Poland is further because, to-date, the topic of the tourism's and aviation's GHG emissions has largely been explored from the 'western' and 'developed countries' perspective (Dillimono and Dickinson 2015). The recent increase in tourist numbers outside the 'western' markets suggests that this scope should be re-considered and extended, with the 'emerging' tourism and air travel markets, such as those in East-Central Europe, calling for more research attention (Dickinson *et al.* 2013).

2. Background to research and the geographical context of analysis

2.1. Public opinion on (aviation) biofuels

Biofuels occupy a noticeable position in the international research agenda given the crucial role they are attributed to play in fulfilling the future world energy demand and reducing its carbon intensity (Demirbas 2007). This is reflected in the growing number of literature outputs and research grant applications made on this topic in the last decade (Yaoyang and Boeing 2013). While existing research on biofuels shows its truly global penetration, it also pinpoints the limited number of subject

categories from the perspective of which the topic of biofuel technology has been scrutinised. Comprehensive literature reviews conducted by Mao *et al.* (2015) and Yaoyang and Boeing (2013) indicate that the bulk of research on biofuel technology originates from 'hard sciences' with the 'soft sciences' disciplines being substantially under-represented. This may partially explain the reason for the yet sparse nature of peer-reviewed studies that have been dedicated to the examination of public opinion on biofuels, including public knowledge and public perception of its environmental (dis)benefits (Cacciatore *et al.* 2012). Importantly, the issue of biofuel safety as perceived by prospective users has never been comprehensively examined, although safety considerations play an essential role in consumer choice of technological innovations (Liew *et al.* 2014). While the situation is gradually changing and increasingly more studies start looking at biofuels from a social sciences perspective, the need for more rapid development of this research field has been repeatedly emphasised (Fung *et al.* 2014).

In addition to the limited stream of research which has set to better understand public attitudes to biofuel technology, the spatial scale and the sectoral scope of analysis demonstrated by existing studies have also been restricted. Existing research has been primarily concerned with the application of biofuels in road transportation (see, for example, Månsson *et al.* 2014; Sawanidou *et al.* 2010; van de Velde *et al.* 2009). The aviation industry, where biofuels are anticipated to play an increasingly important role in the future, has been understudied (Kousoulidou and Lonza 2016). The study by Filimonau and Högström (2017) is pioneering in this sense, but limited in terms of the research tool used and the socio-demographic profile of the surveyed population achieved, which hampers generalisability and representativeness of its outcome.

Next, while research on public opinion on the use of biofuel technology within the sector of road transport is limited, it has further generated a set of commonalities and contradictions, which makes it cumbersome to outline an established pattern of results (Cacciatore *et al.* 2012). The literature reports significant variations in public attitudes to biofuel technology as adopted in road transport, including the levels of public knowledge, recognition of the carbon benefits associated with its use, the degree of social acceptance and public willingness-to-pay (Delshad *et al.* 2010; Rohracher *et al.* 2003; van de

Velde *et al.* 2009). Given the limited number and the varying outcome of the studies on public opinion on biofuel technology, it is problematic to develop effective, research-informed policies that would aim to promote more sustainable, publicly recognised and societally accepted sources of energy and facilitate their broader integration into transportation sectors.

Lastly, the geographical coverage of existing research on public opinion on biofuels has been incomplete with the bulk of studies examining the issue in the context of 'developed' countries in Western Europe, North America and Australia (see, for example, Delshad and Raymond 2013; Fung *et al.* 2014; Wegener *et al.* 2014). The research agenda on public opinion on biofuel technology in countries with 'developing' and 'transitional' economies has been less established (Chin *et al.* 2014). This calls for a change given that these markets hold significant potential for the production and adoption of biofuels (Peters and Thielmann 2008). This is also because many 'developing' countries and countries with 'economies in transition' are now characterised by the substantial pace of economic development, which is reflected in the growing energy and fuel demands. Evidence suggests that the economic growth in developing markets is often enabled by, and also serves as a facilitator of, tourism (Oh 2005); this, in turn, is correlated with the rise in flying. To achieve the goal of environmental sustainability, the increasing energy and fuel demands in the 'developing' and 'transitional' economy markets, including the energy demands attributed to tourism and its sector of aviation, should be fulfilled via the supply of more carbon-benign energy feedstock, such as biofuels.

Poland is a 'transitional economy' in East-Central Europe. Research on biofuel technology in its national context mirrors the limitations attributed to the studies carried out at a global scale. While the potential of the country to become a regional leader in the development of biofuels has been recognised (Kondili and Kaldellis 2007), the amount of research which has been conducted in this domain is small, while the scope of analysis is restricted to the evaluation of the technical feasibility of this technology's rollout in the market in question (Ericsson, 2007; Igliński *et al.* 2011). The literature review has identified no peer-reviewed international publications that would look at public opinion on biofuels in Poland *in general*, let alone on its application within the sector of aviation.

2.2. Tourism and aviation market in Poland

Poland is recognised as one of the most steadily developing tourist markets in Europe, with UNWTO (2015) estimating the growth of being equal to circa 3 % per year. This makes Poland the second largest tourist market in East-Central Europe after Russia and one of the top-10 most visited destinations in Europe (UNWTO 2015). The rise in inbound tourism in Poland is attributed to the growing recognition of the country as an attractive destination among 'western' tourists (Gołembski 2014). Poland has rich historical and natural heritage, which appeals to various categories of holidaymakers (Faracik 2012). Furthermore, the tourism infrastructure in Poland is rapidly improving, which provides 'western' tourists with the required level of amenities for comfort holiday-making (Mintel 2012). Lastly, low holidaying costs in Poland constitute a major attraction factor (Turner 2014). As for Polish outbound and domestic tourism, it has recently increased due to the enhanced standards of living, which has accelerated the development of the national 'middle class' whose representatives choose to spend their disposable income on tourism and leisure-related activities (Górka 2007).

The steady tourism growth in Poland is facilitated by the well-developed transportation sector where aviation has an important role to play (Mintel 2012). According to Central Statistical Office (2015), air travel accounts for about 15 % of inbound and outbound journeys made with tourism and leisure-related purposes in Poland. This figure is substantially lower than the average of 36 % across EU (Mintel 2009 cited Dickinson *et al.* 2013), which can be partially explained by the preference of Polish tourists to holiday domestically and in neighbouring countries, such as Germany, Czech Republic and Slovakia, as these destinations can be easily reached by road transport. This is also because a large number of inbound tourists come to Poland from non-EU states in the east (Russia, Belarus and Ukraine) that represent the countries that Poland has traditionally had weak air connections with, due to their geographical proximity and the under-development of the national aviation markets (Central Statistical Office 2015)

The share of aviation in inbound and outbound tourism in Poland is however growing (Mintel 2012) as increasingly more Poles choose overseas holidays (Central Statistical Office 2015). This is further due to the growth in inbound tourism from Western Europe and North America with tourists

arriving from these regions to Poland by plane (Mintel 2012). A significant portion of the future aviation growth in Poland is attributed to labour migration between Poland and countries of Western Europe, where low cost carriers (LCCs), predominantly operating from regional airports, account for the largest share of increased air traffic (Burrell 2011). Lastly, closely linked to labour migration, the Polish aviation market is set to grow due to the increase in visiting friends and relatives (VFR) tourism (Janta *et al.* 2015) which is, again, facilitated by LCCs.

The potential of integrating biofuel technology into the Polish aviation sector remains unexplored. While a number of experiments have been performed by the industry representatives and research institutions (Clean Tech Aviation 2015), these all have been small-scale projects whose outcome is unavailable in English. To-date, biofuel research in Poland has focussed on the feasibility of feedstock production (Bełdycka-Bórawska *et al.* 2016) and its implications for national food security and rural development (Budzyński *et al.* 2015), with no links to aviation. Given the air travel sector and the tourism industry in Poland are growing, and there is political commitment in the country to reduce the carbon intensity of the national economy (World Bank 2011), it is fair to suggest that biofuels should be given more consideration by national stakeholders as an instrument to curb the GHG emissions from flying.

2.3. Summary

A critical literature review on public opinion on biofuel technology signifies a substantial knowledge gap in terms of the sectoral and spatial coverage. Largely driven by tourism, the global aviation sector is growing, which implies increase in the associated GHG emissions and the need for their reduction. A large share of this growth is attributed to the 'emerging' tourist destinations. The carbon intensity of flying can be minimised by biofuel technology, which has been trialled in aviation. Success of adopting biofuel technology can be determined by the levels of its public knowledge, societal acceptance and consumer perception of safety. This paper contributes to knowledge by examining public attitudes to the use of biofuels in aviation in one of the less established, while concurrently most rapidly developing, aviation markets in Europe, Poland. The research questions this study aims to answer are: 1) what consumers of air travel in Poland know about the use of biofuels in

aviation; 2) what advantages and disadvantages do consumers of air travel in Poland associate with the use of biofuels in aviation; 3) how/if safety considerations affect consumer perception of the use of biofuels in aviation in Poland.

3. Research design

This study employed a survey research instrument for primary data collection. A questionnaire was developed based on a number of themes that had emerged from the literature review and in the result of a qualitative pilot study. In response to the findings of previous research on public opinion in Poland, the questionnaire was adopted to fit the Polish context. Dickinson *et al.* (2013) demonstrated limited public understanding of the tourism-climate change discourse in Poland, partially due to the less established subject-related terminology in Polish language. Hence, a survey was designed with this challenge in mind, employing simple terms, avoiding academic jargon and explaining the key scientific notions presented, if and when necessary. To address the cross-cultural and language-related biases in research (Brislin 1976), questions were first developed in English; then professionally translated in Polish; and then followed on with back translation in English by two bilingual academics. Lastly, the questionnaire was pilot-tested with 10 volunteers, who were Polish native speakers, to ensure clarity of questionnaire items.

The questionnaire incorporated items on: general public awareness of biofuel technology; public awareness of its application in the aviation industry; public knowledge of the benefits and disbenefits associated with biofuel use in the air travel sector; and public attitudes to safety of aviation biofuels. These items were operationalised using a 5-point Likert scale. Additional questions were employed to examine the past travel behaviour of participants and their knowledge of the inter-linkages between air travel and climate change. Lastly, socio-demographic data were collected. Alongside the questionnaire, a brief information sheet was devised containing some key facts about the progress achieved in the biofuel adoption by aviation to-date. More specifically, this information sheet featured details on the number of biofuel-driven flights made globally to-date alongside the names of the airlines involved in biofuel trials. It was foremost designed to be issued to those survey participants who did not know about the application of biofuel technology in the air travel sector. The information

sheet was given to study participants in the middle of the survey, i.e. after the questions designed to test public knowledge on biofuel technology and its use in aviation have been asked. Purposefully, it did not contain any data on the socio-economic and environmental (dis)benefits of aviation biofuels alongside their safety regulations to ensure that no bias was imposed on the attitudinal items of the questionnaire.

The survey instrument was administered face-to-face to Polish residents of Krakow, the Malopolska region. Krakow was chosen because it is the country's second largest city, which hosts Poland's second busiest airport and represents the most popular tourist destination in the country (Central Statistical Office 2015). The self-completion survey was conducted in Krakow city center over a three-week period in June–July 2015 using a non-probability sampling strategy on a 'next-to-pass' basis, i.e. the public were randomly approached by researchers with a request to fill in the survey questionnaire and, when one questionnaire was complete, the next person to pass the survey point was requested to partake. During the survey deployment, the researchers remained available to ensure any queries raised by participants and related to the questionnaire items were addressed in a prompt manner. No incentives were given.

In total, 306 usable questionnaires were collected. Given the exploratory nature of this project, collected data were analysed using descriptive statistics. The nonparametric Mann-Whitney U test and ANOVA Kruskal-Wallis test were employed to analyse the differences and establish correlation in public opinion.

Because the survey was deployed in Krakow which is a leading educational center in Poland with a large number of university campuses located in the city's center, the survey sample was skewed towards the younger and more educated demographics (Table 1). Younger Poles were more responsive to the survey (response rate of circa 80%) compared to the elderly (response rate of about 10%). Similar response pattern was recorded in other studies conducted in the Polish context (Dickinson *et al.* 2013). While this is a major limitation of the study, the younger consumers are the ones who are likely to become active users of tourism and aviation services in the future. Concurrently, aviation biofuels represent a future, rather than current, technological solution to

mitigate the carbon footprint in tourism and it is therefore important to understand opinion on aviation biofuels among the current as well as the future users.

[Insert Table 1 here]

4. Data analysis and discussion

4.1. Travel behaviour

Table 1 indicates that the overwhelming majority of participants have been on an international holiday in the past three years with Western Europe (57%), Asia (12%) and Africa (10%) being the top-3 destination choices. Car was the most widely used means of transportation abroad (59%), closely followed by air travel (55%) and then coach (45%). Those who travelled with tourism purposes in the past three years can be described as active holidaymakers because the mean number of tourism journeys undertaken was reported as 3.88 (SD=3.196) per year. This is in line with statistics showing that outbound tourism in Poland has been rapidly developing due to the increased travel patterns among the young, fairly wealthy and educated consumers (Central Statistical Office 2015).

4.2. Knowledge of the inter-linkages between tourism and climate change

The study found that the majority of the Polish public attributed small carbon impacts to air travel and international holidays. The contribution of flying and holidaying to global GHG emissions was seen as significant by only 47.5% and 39.9% of survey participants, respectively. Instead, and similar to Dickinson *et al.* (2013), travel by car with leisure and commuting purposes and use of public transportation were viewed as the prime producers of carbon impacts. These survey items were pinpointed as the significant contributors to global GHG emissions by 77% and 62.6% of survey participants, respectively. This demonstrates that, despite the continuous efforts applied by various stakeholders in Poland to raise consumer awareness about the issue of climate change and its main contributors (see, for instance, Climate-ADAPT 2015), public understanding of the crucial role played by the tourism industry in the global carbon footprint production remains limited in the context of East-Central Europe and should therefore be reinforced.

4.3. Knowledge and understanding of biofuel technology and its application in aviation

Limited public understanding of the significant role played by aviation in carbon footprint generation implies that voluntary behavioural changes aimed at reducing the carbon intensity of tourism (for example, via taking fewer flights; going on holidays less often but staying at a destination longer; and holidaying closer to home) do not yet represent a feasible, stand-alone carbon mitigation opportunity in the context of Poland. This is in line with studies conducted on this topic in other geographical and socio-economic contexts, both in Europe and beyond (Cohen and Higham 2011; Higham *et al.* 2015; Gössling *et al.* 2012). This underlines the important role of other mitigation approaches, such as technological innovations, designed to decarbonise the sector of air travel. According to the literature, technological innovations have greater chances to succeed in the market when they are recognised and approved by prospective users.

Biofuels as a *generic* tool for carbon mitigation were recognised by the majority (83.8%) of participants, which can be partially attributed to the success of educational campaigns developed across EU to enhance public awareness of this carbon footprint reduction option alongside the extensive coverage of the topic of biofuel technology in the national mass media (Cacciatore *et al.* 2012). However, closer analysis shows that public knowledge on biofuel use specifically within the sector of *aviation* is significantly less established, with only 18.1% participants claiming to be aware about the application of biofuels in the air travel sector. Statistical non-parametric tests identified no association between the participants' gender ($p=0.603$), age ($p=0.737$), level of education ($p=0.950$) and their knowledge of biofuel use in aviation. Poor public awareness of the application of biofuel technology in aviation was homogeneous across all socio-demographic profiles within the studied sample. This signifies a substantial knowledge gap, which ought to be overcome. This also suggests that, while biofuels have long been trialled by airlines, these efforts have largely remained unnoticed by the public in Poland. Given that biofuels are set an important role to play in the future of the aviation industry, public understanding of the progress made by airlines to-date in reducing the carbon intensity of their operations should be enhanced. This is in line with the willingness of the Polish public to learn more about the use of biofuels in aviation alongside the public desire to see the broader adoption of this technological innovation in the sector of air travel (Figure 1). The latter finding

demonstrates that the levels of societal acceptance of the more carbon benign energy generation technologies in Poland are high; this implies that, despite the vagueness in public understanding of the benefits and disbenefits of biofuel use in aviation (see section 4.4), the Polish society is generally 'ready' for the broader deployment of biofuels in the air travel sector.

[Insert Figure 1 here]

4.4. Public understanding of the benefits and disbenefits of aviation biofuels

While the Polish public associated the application of biofuel technology with certain environmental benefits, they concurrently had limited understanding of the challenges attributed to biofuel use in the sector of air travel (Figure 2). Statistical non-parametric tests revealed no association between the key socio-economic characteristics of the sample profile, most notably gender, age and the education level, and these questionnaire statements. No relationship was further established between public perception of the (dis)benefits of aviation biofuels and frequency of flying. Cross-tabulation was run to explore if those 74.9% of participants who believed that biofuels were a good way to make aviation more climate-friendly (Figure 2) also agreed that the broader adoption of biofuels would negatively affect the global food production. Within this sample, only 23.9% participants agreed on both items while the majority (54.8%) remained undecided, which indicates poor public understanding of the inter-linkages between biofuel use and global environmental changes. Lastly, while the majority of participants saw biofuels as a facilitator of more carbon-benign aviation, less than half agreed that the advantages of biofuel use in aviation outweighed its disadvantages (Figure 2). Potentially, this may further demonstrate limited public understanding of the environmental, positive and negative, repercussions of biofuel use among Polish tourists which translates into such 'neutral' attitudes.

Similar outcome was recorded by the studies conducted in other sectoral and geographical contexts, especially in developing countries (Balogh *et al.* 2015; van de Velde *et al.* 2009; Zhang *et al.* 2011). This suggests that the public in Europe, and especially in East-Central Europe, where the scientific discourse on climate change and aviation has been less established (Dickinson *et al.* 2013), should be provided with more comprehensive, carefully balanced information outlining the pluses and

minuses of this renewable energy technology in order to raise public awareness and enable more educated consumer decision-making. Provision of information increases public knowledge but does not necessarily trigger positive behavioural changes, which is due to the complex nature of consumer decision-making (Abrahamse *et al.* 2005), especially in the context of tourism and its sector of air travel (see, for example, Barr *et al.* 2010; Davison *et al.* 2014; Miller *et al.* 2010). This notwithstanding, information provision represents the very first, and arguably the most fundamental, step in architecting pro-environmental consumer choice (Olander and Thogersen 2014), especially in emerging and transitional markets, which emphasises its importance in the Polish context.

[Insert Figure 2 here]

4.5. Safety of biofuel use in aviation

Although safety of aviation biofuels represents an issue of strict regulation (IATA 2013), the Polish public raised certain concerns over the safety of biofuel use in aviation (Figure 3). This is in contrast to public perception of biofuels as a safe alternative to conventional fuels in road transport (Question='Biofuels are safe to use in road transport'; M=2.15, where 1=Strongly agree and 5=Strongly disagree). The difference is not however statistically significant (p=0.217) and most likely to occur due to the substantial knowledge gap on the application of biofuel technology in the sector of air travel, as established earlier. This further underlines the necessity to enhance public recognition of biofuels as a safe, and more carbon benign, type of aviation fuel in Poland. Importantly, statistical non-parametric tests identified no association between the participants' key socio-economic characteristics and public perception of aviation biofuel safety, which demonstrates the homogeneity of public opinion on this issue in Poland.

[Insert Figure 3 here]

The survey outcome suggests that the most effective way to reinforce public knowledge on biofuel use in aviation in Poland is through the information channels that are not directly affiliated with the national government and, to a lesser extent, the national air travel industry. Polish tourists demonstrated limited trust in these stakeholders (Figure 3), which is confirmed by other studies

conducted locally (CBOS 2004). The 'third sector' organisations may therefore represent a more effective instrument of public opinion architecture in Poland. Given that public distrust in national governments is a legacy of communism (Rose 1994), it can be suggested that a similar approach should be employed for the reinforcement of public knowledge and consumer environmental awareness in the context of other post-communist societies in East-Central Europe, such as Czech Republic, Slovak Republic and Hungary.

Polish tourists were largely unable to compare safety of biofuel use in aviation and road transport, with the majority of survey participants remaining 'undecided' on this topic (Figure 3). Again, this is likely to be attributed to limited public knowledge on the application of biofuel technology in the context of air transport and the consecutive necessity for the reinforcement of this construct. This can be reached through the dedicated information and public-awareness raising campaigns that are best to be delivered by the civil sector's representatives.

Lastly, when explained about the potential of biofuel use in aviation and presented with the key facts on its adoption by the sector to-date via a tailor-made information sheet (see section 3), this technology was generally viewed positively by Polish tourists (Figure 3). This indicates that the society in Poland is likely to accept the broader deployment of biofuels as a carbon abatement technology in the air travel sector, subject to reinforcing public knowledge on the benefits associated with its use alongside emphasising the notion of its safety. This signifies substantial prospects for the application of biofuel technology in aviation and outlines its potential for carbon mitigation, which has gained preliminary 'approval' of prospective users in Poland.

5. Conclusions and future research

This study examined public opinion on the application of biofuel technology in aviation in the context of an emerging tourist market in East-Central Europe. It found that while the potential of biofuels as a generic carbon abatement instrument was well recognised, public awareness of its specific use in the air travel sector was low. Likewise, there was limited understanding of the challenges attributed to the adoption of biofuel technology in aviation, while the desire for having more information to rectify this gap in public knowledge was recorded. This calls for the

reinforcement of public opinion, which can be achieved by designing dedicated educational and awareness-raising campaigns. The study found that these would be best deployed by organisations representing the Polish 'third sector', which was due to limited public trust in the national governmental and business institutions.

The study established that, due to limited public knowledge on the application of biofuels in aviation, Polish tourists were somewhat concerned about this technological innovation as being a safe alternative to conventional aviation fuels. This suggests that emphasising aviation biofuel safety should become an integral part of all public awareness enhancement initiatives as developed in the Polish context. Once public recognition of biofuel use in aviation, including its safety, has been reinforced, there is better potential for this technology to win consumer confidence in Poland.

This study outlined promising research avenues. It showed that public opinion on biofuel use in aviation should be more closely examined in the different geographical, socio-economic and political contexts. Aside from improving general understanding of what the public know and what they think about this technological innovation, thus critically evaluating the prospects of its successful market rollout, this may help establish the region-specific differences that are to be taken into account when designing educational and consumer-awareness raising campaigns. In the context of Poland, for example, limited public trust in the national governmental institutions suggests that educational and consumer awareness-raising campaigns are best to be run by non-governmental organisations. This statement may hold true for other markets in East-Central Europe, where the substantial levels of public distrust in the national institutions of power have been inherited from the communist past. Furthermore, the technology-evoked 'rebound effect' (Druckman *et al.* 2011) should be better understood in the context of research on public opinion on biofuels. The 'rebound effect' implies that consumers prefer, or even become more frequent users of, the products and services that they associate with certain, often environment-related, benefits. While biofuel technology can reduce the GHG emissions from aviation, its positive effect can be offset by the increased number of flights undertaken by tourists on the assumption that these are driven by more carbon-benign fuels. Lastly, tourist willingness-to-pay for biofuel-driven flights represents an interesting research topic, both in the

context of developed and emerging economies. Albeit being hypothetical, a study on the consumer preparedness to pay for flights producing lower GHG emissions would demonstrate the potential market reaction to the prospects of their adoption.

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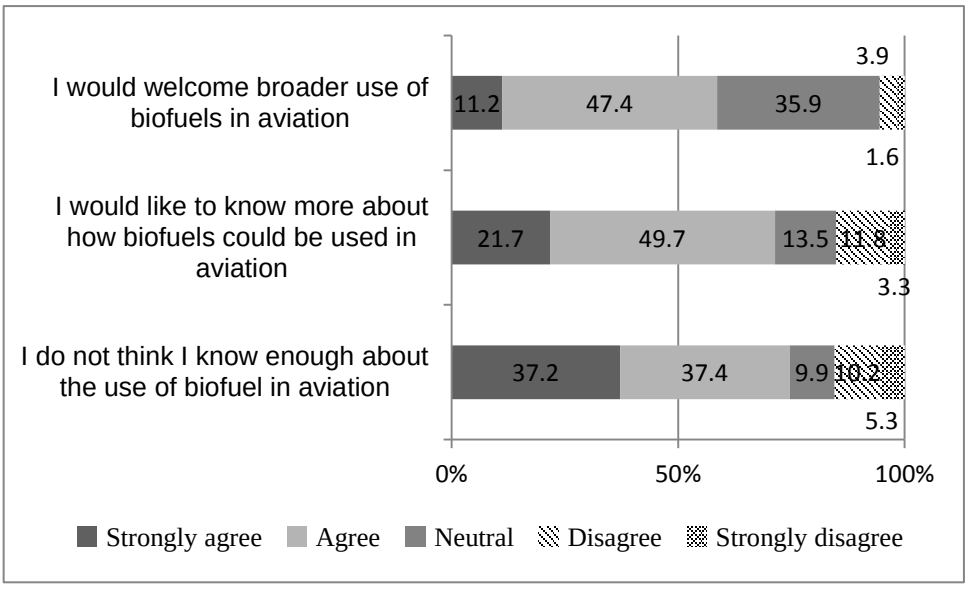
Table 1**.** Sample profile (n=306)

Gender		**Personal salary**	
Female	57.8%	Below nation's average	45.3%
Male	42.2%	Above nation's average	19.2%
		Refused / Prefer not to say	35.5%
Level of education		**Occupation**	
		Retired	2.6%
Secondary school	44.6%	Student	53.9%
Technical education	4.6%	Unemployed	1.3%
University and above	47.9%	Full-Time employed	31.1%
No formal education / Other	2.9%	Part-Time employed	11.1%
Age		**Travelled abroad with holidaying purposes** (in the last 3 years)	
16-24	54.5%		
25-34	24.2%		
35-44	9.2%	Yes	87.8%
45-54	7.2%	No	12.2%
55-64	3.6%		
65 and over	1.3%		



Mean (M)

2.38

2.25

2.09

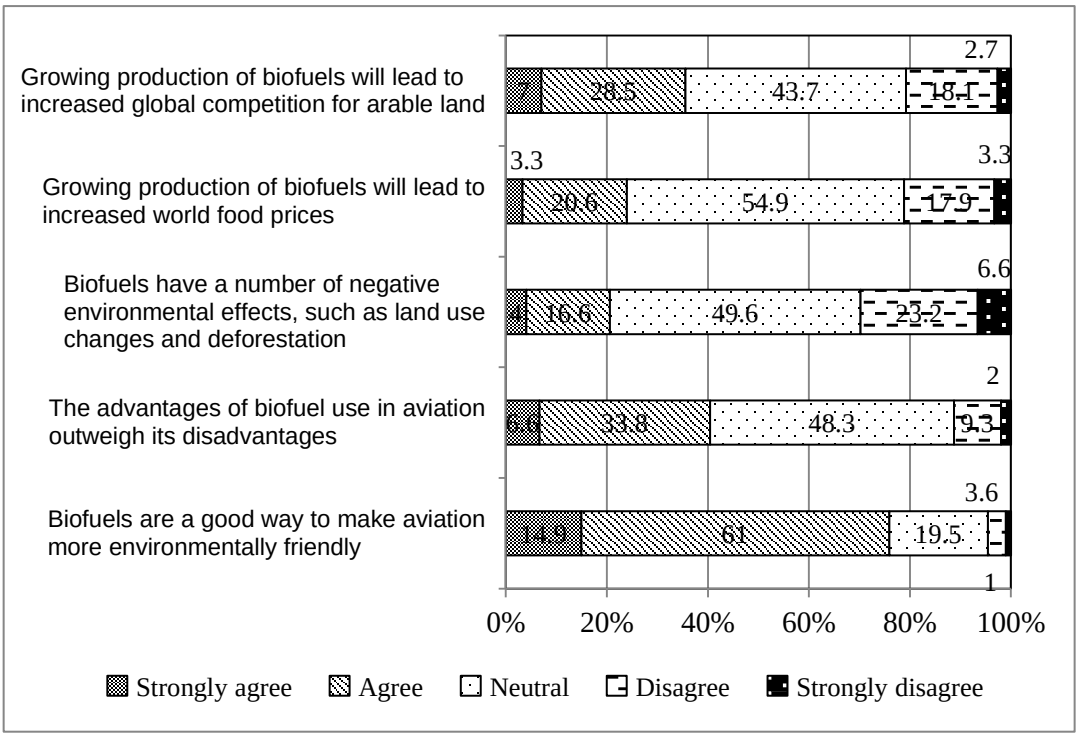
1=Strongly agree;

2=Agree; 3=Neutral;

4=Disagree;

5=Strongly disagree

Figure 1. Public knowledge in Poland of biofuel use in aviation.



Mean (M)

2.81

2.97

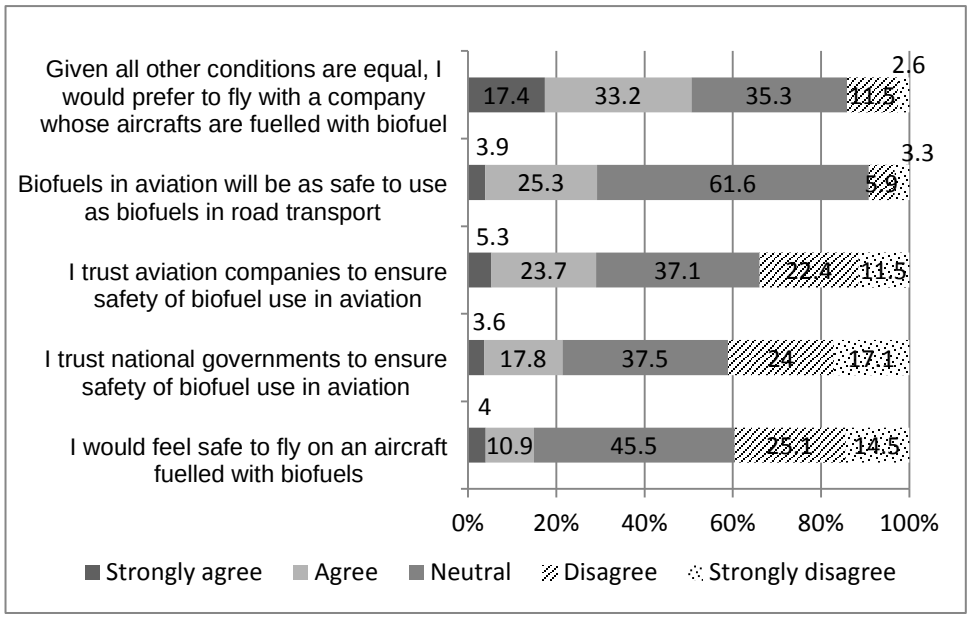
3.12

2.66

2.15

1=Strongly agree; 2=Agree; 3=Neutral; 4=Disagree; 5=Strongly disagree

Figure 2. Public perception of the benefits and disbenefits of biofuel use in aviation.



Mean (M)

2.59

2.79

3.11

3.33

3.35

1=Strongly agree;

2=Agree; 3=Neutral;

4=Disagree;

5=Strongly disagree

Figure 3. Public attitudes to the safety of biofuel use in aviation.