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CARBON FOOTPRINT IN THE PASSENGER AIR TRANSPORT INDUSTRY: A CASE STUDY OF A GERMAN LOW COST CARRIER

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Abstract: *The airport industry causes about three percent of human induced global warming and due to an industry's growth of approximately five percent per year the share is likely to rise up to 15 percent by 2050. Thus, the passenger air transport industry will be obligated to participate in the greenhouse gas emission trading scheme starting in 2012. Therefore this industry sector is being forced to measure their carbon footprint (CF). Moreover, through a growing public awareness on climate change the CF approach has increased in importance. Calculating the CF of an airline represents an extensive assessment due to the high interdependence within the industry's supply chain, so that support through industry-specific calculations tools becomes necessary.*

This paper develops a proposal for a standardized procedure of carbon footprinting in the passenger air transport industry. This proposal is based on a literature review and on the widely applied "Greenhouse Gas Protocol". The standard differentiates direct and indirect emissions within scope 1, 2 and 3 examinations. After the development of industry-specific questionnaires for each scope a case study within an European low cost carrier was conducted in order to test the proposal. The questionnaires emphasize the particular situation of the selected airline, but could easily be adjusted for the utilization at other airlines.

The total global warming potential of the selected airline is approximately 700 kilotons CO_2e and 111.9 grams of CO2e per passenger kilometre. About 90 percent of the generated GHG emissions are caused by direct emissions; the indirect emissions represent only a small share of the airline's emissions. In comparison to reported benchmarks of competitors the calculated emissions are in the mid-range.

The calculation of the CF and its comparison to competitive European airlines shows that a standardized assessment procedure is essential to enable comparability. This article can provide a basis for such a standardized method.

Main contents of the Keywords: carbon footprint, air transport industry, case study

I. INTRODUCTION

The air transport industry causes about 3 percent to human induced global warming. [1] But with an industry's growth of approximately five percent per year, the share is likely to rise up to 15 percent by 2050 [1], [2]. Thus, the passenger air transport industry will be obligated to participate in the European greenhouse gas emission trading scheme (EU ETS) starting in 2012 [3]. Therefore this industry sector is being forced to measure their climate change impact which can be examined through a life cycle consideration that comprises all climate relevant activities along the firm's supply chain.

Life Cycle Assessment (LCA) is a systematic analysis of environmental impacts of products, processes or services during their entire life cycle. This method collects and evaluates all input (material and/or energy) and output (products and undesired by-products) streams during production, use and disposal phase and the related upstream and downstream processes (e.g. production of raw materials and supplies).

The carbon footprint (CF), as a specific method of LCA, assesses the emissions of carbon dioxide (CO_2) or greenhouse gases measured in CO_2-equivalents (CO_2e), which are caused by human activities [4]. The method, which is based on the concept of „ecological footprinting" of Wackernagel and Rees [5], can be regarded as a subset of LCA that is limited to the single impact category "global warming potential" (GWP) [6]. Even though the concept has been used for many years [7], its definition remains subject to discussion (see [4]) and is not yet acknowledged as a generally accepted indicator [8]. In spite of the current lack of legal regulation, a growing number of international, national and sectorial institutions work towards standardizing the measurement and assessment of greenhouse gases in general or specific guidelines and calculation tools [9]. These works are in particular the "greenhouse gas protocol (GHG protocol)" [10], as well as the guidelines of the Carbon Trust [11], the „UK Department for the Environment, Food and Rural Affairs" [12], and the International Organization for Standardization (ISO) [13]. The CF has gained relatively large publicity as public awareness on climate change and corresponding demand on climate relevant information increasingly forces manufacturers to declare the climate impact of their products and services [7], [14]. Thus, specific calculation tools are necessary [9]. The relatively simple approach can serve as a facilitator to further increase the utilization of life cycle approaches in organizations and decision making contexts [15], [7].

But also the globally operating air transport industry works on its own industry standards through various European and international associations. The "International Air Transport Association" (IATA) developed a strategy that targets "carbon-neutral growth" from 2020 and "zero-carbon-growth" from 2057 [16]. The "International Civil Aviation Organization" (ICAO) coordinates standardization and initiatives globally and developed a range of standards, policies and guidance material in order to address climate change in technological and operational improvements. The organization regularly reports advances in the industry [17]. The "Advisory Council for Aeronautics Research in Europe" (ACARE) aims to coordinate research activities for aeronautics in Europe and has laid down its emissions reductions goals in the "Vision for 2020" [18]. The British organization "Greener by design" seeks for operational, technological, economic and regulatory options for limiting aviation's environmental impact. They develop innovative technology and design concepts to reduce emissions and provide best practices on technological standards [19].

The CF approach itself has been frequently applied in the aviation industry. Most analyses focus on the impacts of jet fuel (kerosene) burning. Moreover, the internationality of the industry complicates the allocation of greenhouse gas emissions as emissions are not bounded by national borders [20]. Therefore, many papers examine aviation emission on a global perspective. In 1999, the IPCC evaluated the impact of aviation to climate change. These findings mostly represent the basis for current research and discussions. The main issues of current research relate to efficiency improvement potentials for the reduction of greenhouse gas emissions (see the works of [20], [2], [21], [22], [23]), the allocation of CO_2 emissions from aviation (e.g. [24], [20]), specific calculation methods (e.g. [25], [26]), comparisons within the transport sector (e.g. [27]), and the role of airports and tourism in combination with air travel (e.g. [28]). The Global Emission Model for Integrated Systems 4.5 (GEMIS) provides average CF value for air transport processes [29]. The Carbon Disclosure Project (CDP), which reports GHG emissions of about 3,000 participants in various industries, also contains information of major airlines from around the world. The CDP-reports of airlines with similar operations show that all of them report scope 1 emissions but only a few present scope 3 emissions.

Scope 1 to 3 emissions

Climate relevant life cycle inventory data of an organization stems from direct emissions through internal on-site activities as well as indirect emissions through external off-site activities in pre- or post-processing of the respective goods and services [4]. For an airline, climate relevant activities comprise the operation of aircrafts, as well as the handling of passengers and freight on the ground and in the air, and administrative service and air traffic management (cf. [20]). For a clear calculation of the CF the organizational and operational boundaries have to be assessed. The operational system boundary specifies which material flows and emissions are covered in the analysis [13]. This boundary is characterized by the level of corporate influence and is classified by the scopes 1 to 3. This classification aims to delineate direct and indirect emission sources in order to improve transparency, avoid double counting, and provide applicability of the instrument for different organization types [30]. At present, there is no consensus in the scientific community on delineating emission types and system boundaries [4]. Often, calculations focus on scope 1 emissions since the effort for including emissions of scope 2 and 3 is considerably higher [31]. Due to the lack of regulation, the “GHG protocol” has become the unofficial corporate standard and is currently the most widely used instrument [32].

Scope 1 includes all direct GHG emissions. The WBCSD and WRI (2007) specify them as all “emissions from sources that are owned or controlled by the company” such as generation of electricity, heat or steam; physical or chemical processing or transportation of materials, products, waste and employees [10]. Typical scope 1 emissions in the air transport industry are GHG emissions that result from fuel burned in the aircraft engines. The most important flue gases are CO_2 and nitrous oxide (N_2O). Further, methane (CH_4) and other by-product gases are emitted. The fuel use and emissions depend on aircraft type and utilization, as well as flight distance, altitude and the typical flight cycle [33]. The length of a flight cycle depends on the flight distance. Shorter routes are operated in lower cruise altitudes [34].

An aircraft flight is divided into various phases: Taxi (roll on the airfield), take-off and climb-out, cruise flight, and decent flight inclusive landing [34], [35]. These phases can be further separated into two main parts: *Landing/Take-off (LTO) cycle* (all activities near the airport below the altitude of 1000 m (taxi-in and -out, take-off, climb-out, and approach landing)) [33], [36] as well as *Cruise* (all activities that take place at altitudes above 1000 m (climb to cruise altitude, cruise, and descent from cruise altitudes)) [33], [37].

The fuel consumption of the LTO phase can be calculated in two different ways: first, the specific fuel consumption of an aircraft type per LTO-cycle [38] or second, the standard fuel consumption of an average aircraft, separated into LTO cycle and cruise [38]. For the first one the IPCC [38] provides a table of aircraft types and their frequent uses for domestic and international aviation equally. The second approach supplies data for national and international aviations separately. Furthermore the fuel consumption for the LTO cycle is differentiated in old (kerosene consumption per LTO: 1000 kg national, 2400 kg international) and average fleet (kerosene consumption per LTO: 850 kg national, 2500 international). For the average calculations of international air transport IPCC uses the average fuel consumption of 1675 kg kerosene/LTO [39], [40].

The fuel consumption of the cruise phase depends on the length of the flight, that is calculated by the total fuel use minus fuel use in the LTO phase for domestic and international aviation separately.

The emissions of air traffic can be calculated based on average fuel consumption and corresponding emission factors. The fuel jet (kerosene) used in aviation is a mixture of different hydrocarbons, which emits in its (complete) combustion mainly CO_2 and water (H2O). These emissions as well as sulphur oxide (SO_2) depend on the properties of the specific kerosene burned. Emissions of non methane volatile organic compounds (NMVOC), CH_4, carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_x) and N_2O also depend on engine performance, flight altitude and flight phase. However, CO_2, CH_4 and N_2O are the only aircraft emissions that are part of CF.

The emission factors, especially of CH_4 and N_2O, differ in the two phases of flight, LTO cycle and cruise. Thus, the calculation of the relevant material and energy flows has to be accounted separately for each phase and in dependency of domestic or international flights [40], [41]. For the cruise phases the flight emission factors per amount of consumed fuel are used.

Additionally, scope 1 emissions can also result from fuel combustion in car engines. Here, the fuel usage and emissions depend on the car type with its vehicle mass, size of engine, car utilization, the driving distance and the driving behaviour [34], [42]. GHG emissions from fuel combustion in cars can be calculated by the multiplication of the driven kilometres and the vehicle specific emission in g CO_2/km. The emissions by burning the fuels petrol (Otto-Motor) or diesel (Diesel-Motor) are CO_2, NO_X, SO_2, NMHC (non-methane hydrocarbons) and particulate matter. Of the vehicle emissions, only CO_2 is part of the CF. The specific data for every vehicle type is provided by the manufacturer or available in databases [43]; [42].

The **second scope** covers indirect GHG emissions associated with generation of electricity, heat, or steam purchased for consumption in owned or controlled equipment or operations [10], [30]. Electricity, heat, and steam can be produced by burning fossil fuels in stationary combustion units, which immediately results in greenhouse gas and other emissions. CO_2 emissions depend on the energy intensity of a given mode, the fuel carbon content, and the degree of combustion [44]. Alternatively, energy can also be generated by nuclear or renewable sources (e.g. wind, solar). Therefore, each energy supplier provides a different energy mix with different emission factors. Even tough the emissions are physically emitted at the combustion facilities, the emissions are actually a consequence of the activities of the end consumer [45]. The “GHG protocol” bases its GHG estimation method on an emission factor-based methodology. This method calculates GHG emissions by multiplying a level of activity data (e.g. electricity consumption in MWh) by an emission factor (e.g., grams of CO_2 per MWh) [45].

The GHG guide only includes the calculation of CO_2 as it usually accounts for about 99 percent of the GHG emissions from the stationary combustion of fossil fuels. The estimation of other GHG emissions requires much greater efforts [45].

The GHG protocol defines **scope 3** emissions as “other indirect emissions, such as those associated with the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting company, electricity-related activities (e.g., transmission and distribution losses) that are not covered in Scope 2, outsourced activities, or waste disposal” [30]. In addition to this classification a further distinction of scope 3 emissions was made by WRI and WBCSD in 2009. A supplement of the GHG Protocol divides scope 3 emissions into three categories: Upstream scope 3 emissions from purchased products, downstream scope 3 emissions from sold products and other scope 3 emissions. The first category encompasses those emissions “that occur in the life cycle of inputs (i.e., purchased or acquired goods, services, materials, and fuels), up to the point of receipt by the reporting company”. Downstream emissions are “the emissions that occur in the life cycle of outputs (i.e., sold goods and services) subsequent to sale by the reporting company”. Any emissions that do not fit into either of these two categories are subject to “other scope 3 emissions” that are “limited to employee activities such as commuting, which are neither purchased nor sold” [46].

This paper examines the application of the CF approach in the passenger air transport industry. The focus is put on European low cost carriers with short and medium distance flights. Using different developed questionnaires that consider industry-specific characteristics the case study research method is applied. The case is a European low cost carrier, called Aircarbon. The CF will be calculated for every scope and the results will be compared to other airlines.

II. METHODOLOGY

Case studies are a common research method in social science. They are used in many situations to undertake an in-depth investigation of individual, group, organizational, social, political, and related phenomena [47]. Like an explanatory case study according to Yin (2003), this article provides information how an airline could measure its GWP. Throughout the paper a standardized approach for the calculation of a CF in the air transport industry will be developed. The basis for this development builds a questionnaire for the collection of GHG emissions data for a low cost carrier. The real-life context of this investigation is provided through the application of this questionnaire for the collection and calculation of the CF of Aircarbon. Aircarbon is a low cost carrier located in Germany. The destinations are in Europe so that from 2012 every flight is subject to the EU ETS.

The approach of this work shall be based on the guidelines of the GHG protocol. The operational system boundary includes the scopes 1 to 3. Organizationally, the empirical assessment of Aircarbon comprises its European operations. The collection of life cycle inventory data shall be enabled through an industry-specific questionnaire. Subsequently, the emissions data queried by the developed questionnaires from Aircarbon are converted into CO_2-equivalents by considering the emission intensity of each source and weighting of the GWP of non-carbon dioxide greenhouse gases. If specific emission factors are not available, standardized values can be used instead. The aggregated final CO_2-equivalents amount states the airline’s CF.

The **scope 1 questionnaire** collects data on air traffic and vehicle fleet of an airline. The required aircraft fleet data is based on fuel use and of the number of flights that is distinguished in domestic and international air traffic. In both cases, travel volume is determined according to fuel consumption of aircraft types given by IPCC [38] or by standard fuel consumption of an average aircraft fleet for LTO cycle and Cruise. On this basis, the questionnaire asks for the national and international fuel consumption and number of flights if available per aircraft type and, if not, the average consumption over the fleet. The number of national and international flights gives the respective LTO number. For the vehicle fleet the questionnaire intends to retrieve the data for the driven distance per vehicle type and the specific CO_2-emission factor of the vehicle type.

The scope 2 questionnaire intends to retrieve the data for each of the energy types, electricity, heat, and steam, separately. This procedure allows for a detailed analysis. Each section aims to query activity data as well as data for the calculation of the emission factor. Electricity is usually consumed in the office and maintenance facilities, as well as by aircrafts for its supply on ground. For the determination of scope 2 it is necessary to query the ownership and operating status of the office building as only operationally controlled electricity consumption belongs to scope 2. In the case that specific data on electricity supplies are not available, the information on facility space area should be provided. Electricity for consumption can either be purchased or might be generated by the airline itself. For scope 2 analysis only the purchased quantity is relevant. Resold electricity is neither part of this analysis. For the determination of the accurate emission factor, the energy mix of the local energy supplier has to be known. As renewable energy sources can be regarded as carbon-neutral, this share has to be subtracted. For the later derivation of reduction potentials, information about the company's electricity sinks, such as illumination or maintenance, are helpful. The same data is required for the analysis of heat consumption. Steam is usually used for the production of electricity or as process heat. Neither use is likely for an airline. Thus, only steam consumption in maintenance might be expected. The energy consumption data is most likely to be received from the energy supplier. For scope 2 emission factors, the default values of the database "ProBas" will be used.

For the evaluation of **scope 3 emissions** of Aircarbon following categories or sources are relevant: purchased goods and services such as the aircraft itself, food and beverages as well as cleaning agent, the transportation and distribution of the mentioned purchased goods and the purchased fuel for the aircrafts, employee business travel, disposal/ treatment of waste generated in operations, disposal of sold products like the aircraft at the end of their life as well as the employee commuting. Focusing on employee commuting a online survey was established in order to receive information of their commuting behaviour. To calculate the amount of fuel that an employee consumes on her/his way to work, four parameters have to be collected by the survey: Commute mode (transportation mode/fuel type), days commuted using this mode, distance commuted using this mode and passenger miles per litre [48]. For testing the functionality of the survey and to reach its final status, pre-tests were conducted and the GESIS – the Leibniz institute for social sciences – has examined the survey.

III. RESULTS AND DISCUSSION

Based on the questionnaires, Aircarbon provided information on scope 1, 2, and 3 life cycle inventory data for 2009. For neither scope, the data is exhaustive. Thus, it only allows for an approximation in the calculation of the GWP.

Aircarbon only operates a fleet of the rather small aircraft A 319 within Europe. Moreover, information on the number of international flights (larger than 600 km) is not available. Thus, an average kerosene consumption of 850 kg/LTO can be assumed in the calculation. Table 1 summarizes the input data.

TABLE 1: SCOPE 1 INPUT DATA OF AIRCARBON

	Emissions factors 2009			Kerosene/ Emission [t]
	National	International	Average	
LTO	LTO		Kerosene [t]:	53,329
CO_2	3.15	3.15	3.15	167,986.35
CH_4	0.00035	0.00013	0.00024	12.79896
N_2O	0.00012	0.00009	0.000105	5.599545
Cruise	Cruise		Kerosene [t]:	165,380
CO_2	3.15	3.15	3.15	520,947
N_2O	0.0001	0.0001	0.0001	16.538

The environmental impact of the common six GHG emissions in the impact category GWP differ. Thus, each GHG has to be weighted by its GWP to finally obtain the total GWP in CO_2-equivalents. In the combustion of kerosene in aircrafts only CO_2, CH_4 and N_2O are emitted and thus, considered in the CF calculation. The standardized conversion factors used in this work are provided by the IPCC [49]. Table 2 summarizes the results. The Scope 1 emission from the vehicle fleet could not be calculated because the fuel consumption of the cars are not listed.

For the calculation of scope 2, a large part of input data remained unavailable. The energy consumption data provided can be found in table 3. Using the official scientific values of the energy mix for electricity production in Germany „El-KW-Park-DE-2010“ as well as the energy mix for a district heating network “Wärme-Fern-mix-DE-2005/el-mix” of the database ProBas leads to a total global warming potential of 827,6 tons.

TABLE 2: SCOPE 1 GWP OF AIRCARBON

Environmental impac / Environmental aspect	GWP	2009	
	Impact factor	Emissions [t/year]	t CO_2e
CO_2	1	688,933	688,933
CH_4	21	13	269
N_2O	310	22	6,863
Total			**696,065**

TABLE 3: APPROXIMATION OF SCOPE 2 GWP OF AIRCARBON

Electricity		**Heat**		**Total scope 2 [tCO_2e]**
Annual consumption [MWh]	**Emissions [tCO_2e]**	**Annual consumption [MWh]**	**Emissions [tCO_2e]**	
1,297	798.7	154.5	28.9	**827.6**

The Aircarbon’s scope 3 emissions only encompasses emissions from the employee commuting. Data regarding other categories could not collect during the investigation period. For the evaluation of the emissions of employee commuting three different emission factors for each transport mode were used. In the end, the results are averaged to incorporate the different emission factors into one figure. Based on the emissions factors from the EPA-guidelines [50] the average CO_2 emissions per employee per working day are 8.1 kilograms. This corresponds to an output of 1,678 kilograms of CO_2 for 207 possible working days. This includes an average of 30 vacation days and approximately 8 days of absence due to illness. For a total of 1,015 employees the amount of 1,703 tones for the year 2010 were estimated. Using other emission factors the average emissions of CO_2 account between a little less than 7 kilograms per person DEFRA (2008) and 7.5 kilograms [51]. This corresponds to the amount of 1,439 kilograms of CO_2 for the year 2010 or 1,549 kilograms. For the entire staff the amount is equivalent to a quantity of 1,460 tones of CO_2 or 1,549 kilograms. Based on these the results the average value GWP of 1,578 tones CO_2 are calculated from Aircarbon's employee commuting emissions for the work year 2010.

Comparing the GWP of the three scopes, it is obvious that scope 1 accounts by far for the largest amount. Finally, the total global warming potential of Aircarbon's (reported) GHG emissions is about 700 kilotons CO_2-equivalents.

A closer consideration of the data provided by the selected benchmark airlines, exhibited in table 4, shows that these are also biased. For instance, Finnair only included aviation in its scope 1 consideration, while Iberia also refers to emissions from boilers and generator sets (natural gas or diesel) and vehicles that are owned or rented by Iberia [52]. Lufthansa only included electricity data in scope 2 and together with Iberia only calculated carbon dioxide emissions (not equivalents). Only three out of seven benchmarks consider scope 3 at all. Excluding scope 3, the climate impact of an airline can easily be improved through outsourcing of activities. Moreover, the data originates from different years (2008 and 2009).

Apparently, GHG emissions in the air transport industry highly depend on an airline's service volumes (e.g. distance travelled). As shown before, the volumes differ significantly within the industry. For benchmarking, these differences have to be eliminated, so that only the emission intensity of the operations themselves (e.g. caused by the aircraft model and operation) are compared. The application of the relative indicator - revenue passenger kilometre (RPK) - leads to an altered competitive picture. Aircarbon reached 6,241 million passenger kilometres in 2009. With the calculated GWP of about 700 kilotons CO_2-equivalents, the company's emission of CO_2e per RPK is 111.9 grams of CO_2e per RPK. The comparison of the relative indicator of CO_2e emission per RPK shows that TUI achieves the best industry ranks. Aircarbon only achieves an average relative position.

Once again, the significant variances in the results in table 4 show that the data is biased. An obvious factor is differences in the business scope. For instance, Lufthansa is also active in the cargo transport business, while British Airways provides taxi services, both augmenting scope 1 emissions [53], [54]. At the same time, in the functional unit here only considers passenger-kilometres, which finally increases the CO_2 emissions per passenger kilometre. Moreover, the selected airlines used quite different methodologies for their calculation, which shall be discussed in the following.

The calculation of the CF of Aircarbon is based on the GHG protocol. However, at the time being a variety of calculation and reporting procedures are used within the airline industry. For instance, Lufthansa calculates its direct emissions (scope 1) and the indirect emissions (scope 2) of CO_2 according to the requirements of the GHG protocol [53]. Finnair uses the guidelines of the Global Reporting Initiative (GRI) [55], [56]. Other airlines do not specify their approaches at all so that company-own guidelines might be assumed. These different approaches, paired with the variation of included emissions, lead to entirely different results that can hardly be compared. The disparate results received emphasize the necessity of the establishment of a standardized CF procedure within the industry. The examination of such a standard shows that the guidelines of the GHG protocol provide a supporting tool for the identification, determination, and reporting of GHG emissions of airlines. The approach enables a relatively accurate differentiation of scope 1, 2 and 3. However, the boundaries have to be defined clearly in practice.

For scope 1, the protocol offers comprehensive examples of possible direct GHG emissions from combustion of fuels by company owned or controlled mobile combustion sources. The kerosene or other fuel data should be available by controlling entities or technical support. However, for better comparability and precision of an aircraft's emissions, a uniform inventory of consumption and emissions (especially for LTO phase) for each aircraft type should be provided. There is not only an emission difference between LTO and cruise cycle or national and international flights in general, but also between aircraft types and plane ages [38]. A standardized database could bring detailed results of the airline's emissions instead of average calculations. The activity data of the vehicle fleet (km per vehicle type) can be found in the driver's logbook. The specific guidance for the analysis of the consumption of purchased electricity, heat, and steam covers the potential scope 2 emissions of an airline. Energy consumption data should usually be available through the invoices of the energy supplier, the airport operator or the owner of other facilities. However, current, detailed information might be difficult to provide at short notice (delays in invoicing etc.). The facility-specific method is often not available for leased, office-based facilities that are not owned by the reporting company. The determination of scope 3 emissions by employee commuting should apply actual and region specific emission factors. Additionally, CO_2 emission factors are based on aggregated values. Situations such as driving in the inner city and the corresponding higher consumption are not taken into account. The examination of other scope 3 relevant processes, such as outsourced activities, that are required for a comprehensive scope 3 assessment remains subject to further research. To limit the quantification effort for the rather marginal scope 2 and 3 emissions, an airline's footprint will be rather based on default values and estimations than on actual values of the supplying parties.

TABLE 4: COMPARISON OF SCOPE 1 TO 3 EMISSIONS, TOTAL GWP AND GRAMS CO_2E PER RPK OF SELECTED BENCHMARKS

Airline (Year)	Scope 1	Scope 2	Scope 3	Total GHG emissions	RPK	GWP per pkm
Aircarbon (2009)	696,065 tCO_2e	827,8 tCO_2e	1,578 tCO_2	698,471 tCO_2e	6,241 mio. pkm	111.9 gCO_2e/pkm
British Airways (2008) [57]	16,840,627 tCO_2e	105,781 tCO_2e	639,113 tCO_2e	17,585,521 tCO_2e	114,346 mio. pkm [54]	153.8 gCO_2e/pkm

Airline (Year)	Scope 1	Scope 2	Scope 3	Total GHG emissions	RPK	GWP per pkm
easyJet (2009) [58]	4,307,000 tCO_2e	2,000 tCO_2e	n/a	4,309,000 tCO_2e	50,566 mio. pkm [59]	85.2 gCO_2e/pkm
Finnair (2009) [55]	2,246,271 tCO_2e	34,900 tCO_2e[14] (electricity only)	n/a	2,281,171 tCO_2e	19,935 mio. pkm	114.4 gCO_2e/pkm
Iberia (2009) [52]	5,688,709 tCO_2e	26,391 tCO2	28,324 tCO_2	5,743,424 tCO_2	62,158 mio. pkm [60]	92.4 gCO_2/pkm
Lufthansa (2009) [61]	24,228,134 tCO_2	305,947 tCO_2 (electricity only)	n/a	24,534,081 tCO_2	166,371 mio. pkm	147.5 gCO_2/pkm
SAS (2009)	3,203,956 tCO_2 [62]	127,429 tCO_2e[15] (electricity only)	n/a	3,331,385 tCO_2e	25,228 mio. pkm [63]	132.1 gCO_2e/pkm
TUI (2009) [64]	6,297,794 tCO_2e	104,408 tCO_2e	45,167 tCO_2e	6,447,369 tCO_2e	82,553 mio. pkm	78.1 gCO_2e/pkm

The scope specific questionnaires developed rephrase the requirements of the "GHG protocol" under consideration of the specific circumstances in the airline industry. The questionnaires can therefore ease the implementation of a standardized process to enable a broad application. As a comprehensive CF includes all processes and sub processes of an airline, the assessment will affect various stakeholders, such as suppliers and service providers, so that a close communication is necessary. The passenger kilometre can be regarded as a comprehensive functional unit as it includes the two main factors influencing service volume. However, it cannot be the only influencing factor (driver) for GHG emissions. The various corresponding processes are also influenced by e.g. the number of take-offs (and landings), the load factor, or the efficiency of ground handlings. In order to identify reduction potentials, it is necessary to identify all operation's processes that affect GHG emissions such as the handling of passengers and cargo, engineering, as well as administration.

IV. SUMMARY

By means of the LCA method CF, the climate change impact of an European low cost carrier, named Aircarbon, was assessed. Therefore a standardized procedure that considers the industry-specific characteristics and follows the guidelines of the "GHG protocol" was developed. For the European aviation sector such a standard procedure becomes increasingly important, since the industry is not only obligated to participate in the EU ETS starting in year 2012, but also exhibits significant growth. The developed procedure, which incorporates an industry-specific questionnaire, was applied to Aircarbon, which revealed a GWP of about 700 kilotons CO_2-equivalents. The data provided by Aircarbon was not sufficient for a systematic determination of the company's CF. Therefore the analysis faces a large lack of precision. Besides missing emissions data for all three scopes,

[14] CO_2e derived from electricity consumption of 56,693MWh [55].
[15] CO_2e derived from electricity consumption of 207,000 MWh [62].

the calculation also comprised several simplifications. Moreover, the comparison of the results with the published GHG emissions information of European competitors showed that the assessment procedures vary significantly. These obstacles faced throughout the examination of this article emphasize the necessity for the establishment of a standardized procedure within the airline industry that eventually might also include a standard tool, such as a software application. A harmonized instrument facilitates the quantification process and incorporation of emissions of the whole airline's supply chain including both upstream and downstream emissions. Thus, it can enable CF assessments on a regular and global basis with less operating effort. Such facilitation is especially important for scope 2 and 3 since these emissions only represent a relatively small share of an airline's emissions so that their quantification should only cause an appropriate effort. The development of such an instrument remains subject to further research.

It has also been demonstrated that absolute values only provide little information on an airline's environmental performance in comparison to its competitors since passenger and flight volume vary significantly. Instead, the utilization of the relation grams of CO_2e per RPK was suggested. Another research focus could analyse appropriate indicators for cargo air transport.

Besides the finalization of the CF analysis of the airline Aircarbon considering all emissions caused, a consecutive examination could concern company-specific GHG emissions reduction potentials, such as technological efficiency improvements of the aircraft (scope 1), utilization of passive energy (scope 2) or utilization of commuter rail systems by employees (scope 3). The opportunities in the implementation of a corporate CF analysis, especially for scope 2, include a strong focus on efficiency improvements and alternative energy supply, which eventually also provides a positive profitability effect. Moreover, the improvement of reputation among investors and other stakeholders might facilitate access to financial assets and entrance into new markets, such as sustainable tourism. An industry-wide initiative might prevent further legal regulations. However, from a sustainability perspective, the CF as environmental aspect has to be balanced by the social and economic view [2].

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