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1. Introduction

Accommodation, activities at the destination and transportation are the key elements of tourism (Becken and Simmons, 2002) which generate most of its greenhouse gas (GHG) emissions (Byrnes and Warnken, 2006; Dolnicar *et al.,* 2010). The tourism industry is responsible for about 5% of the global carbon footprint (United Nations World Tourism Organisation – UNWTO, 2007) and the share of tourism transport is estimated between 50 and 97.5% (Gössling, 2000; Gössling, 2002; Hunter and Shaw, 2007; Patterson *et al.*, 2007; Peeters *et al.,* 2006). The transit element is recognized as the largest carbon contributor to the GHG emissions from, for example, holiday tours (Gössling and Peeters, 2007) and pilgrimage travel (Hanandeh, 2013) but its share is very variable depending on the distance travelled, mode of transport used and length of time spent at the destination. The destination-based elements of holidays are attributed significantly smaller values of carbon intensity (Gössling, 2002; Gössling *et al.,* 2002). This has, however, been challenged, especially in the context of short-haul tourism. Becken (2002) and Becken *et al.* (2003) argue that if tourists travel to/from a short-haul destination by overland modes of transportation or direct flights, but stay in luxurious hotels and undertake energy-intense activities at the destination, these non-transport elements of tourism may have a much more profound contribution to the total carbon footprint than conventionally accepted. Similar conclusions are drawn by Peeters *et al.* (2006), Chenoweth (2009) and Hunter (2002).

Research on the relative carbon significance of different elements of holiday travel is limited. The number of studies is small and their geographical scope is narrow. This suggests that generalisations should be made with caution when the research outcomes of these studies are projected onto other geographies because the carbon intensity of fuels and energy production varies considerably from region to region. For example, electricity generation in New Zealand, where the studies by Becken (2002) and Becken *et al.* (2003) were conducted, benefits from a large share of renewables (Becken and Patterson, 2006). This suggests a lower carbon intensity of both electricity-driven transport and energy use in hotels in New Zealand if compared to those European countries where the role of renewables in national energy balances is less pronounced. Some studies, such as the study by Chenoweth (2009), used the *global average* GHG emission coefficients for converting the energy consumption in hotels and fuel combustion in vehicle engines into carbon impacts. The applicability of the global average coefficients is limited because of the clear geographical variations in carbon intensity. Furthermore, other studies also rely upon outdated energy use data from the early and mid-1990s (see, for instance, Becken and Patterson, 2006) which fail to account for technological developments.

Previous research has produced some detailed estimates of the GHG emissions from specific holiday journeys, but never investigated in depth the carbon implications of a modal shift in the transit journey to/from the destination. For instance, Becken (2002) and Becken *et al.* (2003) examined tourism patterns in New Zealand which is a remote destination accessible only by air. The study by Chenoweth (2009) looked at a number of holiday destinations which can be reached by various modes of transport but did not perform a comparative analysis of existing travel alternatives.

Duration of stay at the destination is an important variable to examine (Filimonau *et al.*, 2011b). The literature traditionally encourages longer stay which is considered beneficial in terms of the overall eco-efficiency (Gössling *et al.*, 2005; Peeters *et al.*, 2006; Peeters and Schouten, 2006) because the tourists' carbon impacts at the destination are believed to be low (Gössling *et al.*, 2002). The studies by Becken (2002), Becken *et al.* (2003) and Chenoweth (2009) have challenged this standpoint in relation to short-haul holiday travel but provided no critical comparative analysis of realistic holidaying scenarios based on different durations of stay. A carbon impact assessment of different travel scenarios to a single tourist destination can contribute to a better understanding of the most and least carbon-efficient travel practices and identify the most feasible carbon mitigation strategies.

Lastly, existing studies have flaws in the accuracy and comprehensiveness of analysis. This is because they account only for the direct, operational GHG emissions, while ignoring the life cycle-related 'indirect', or embodied, carbon footprint arising from the non-operational phases of a product or service life cycle (see Frischknecht *et al.*, 2007 and Filimonau *et al.*, 2011c for a definition of the 'indirect' environmental impacts). There is evidence that the 'indirect' carbon requirements of tourism can be significant (Berners-Lee *et al.*, 2011; Gössling, 2009; Patterson and McDonald, 2004; Rosenblum *et al.*, 2000). Potentially, they can alter the carbon intensities attributable to different holiday travel practices and to the component elements of the holiday (Filimonau *et al.*, 2011c; Patterson and McDonald, 2004), thus calling for more accurate and holistic appraisals.

Due to the controversy in the literature, there is a need to clarify the carbon intensity of different elements of short-haul holidays and examine the determinant variables causing variations in the absolute and relative magnitudes of GHG emissions. The focus on short-haul holidays is particularly relevant given that short-distance travel remains the mainstay of tourist demand (UNWTO, 2007), especially in Europe where continued growth in short-haul and domestic trips is projected (McKercher *et al.*, 2010). The paper aims to demonstrate the effect of mode shift and length of stay on the total carbon footprint from short-haul holidays. To this end, it undertakes a critical analysis of realistic travel scenarios for British tourists holidaymaking in Southern France. This destination is purposefully selected as it is popular with Britons and because it can be easily reached from the UK by different means of transportation, most notably by direct rail and coach links, thus enabling a more detailed assessment of the impact of modal switch. While the article looked specifically at the carbon footprint of British holiday-makers in Southern France, it is argued that the analysis can be generalized and used to better understand the carbon intensity of short-haul tourism in other West and North European countries (for example, Germany, the Netherlands, Denmark, Sweden). This is primarily because the travel patterns of Britons are representative of other nations in Western and Northern Europe who also tend to fly or drive to the destination (see, for example, Susilo and Stead 2009). The study develops an holistic estimate of the carbon footprint as it applies a new appraisal method which incorporates the advantages of existing carbon impact assessment techniques in tourism and accounts for both direct and ’indirect’, life cycle-related GHG emissions. The paper identifies whether the inclusion of ‘indirect’ carbon footprint impacts on the absolute and relative magnitudes of GHG emissions from a short-haul holiday tour and its specific elements.

The outcome of this study will be of value to those developing guidelines for tourists and tourism organizations to enable more informed decisions about the carbon implications of holidays. Decision-makers can employ results of this study to develop policies directed to encourage more carbon-friendly holiday alternatives among British tourists.

2. Research object and carbon footprint assessment methodology

The research object was short-haul tourism. There is no clear categorization of ‘short-haul’ travel distance in the literature. The definitions vary depending on transport mode and geography. With regard to air travel, the UK Department for Environment, Food and Rural Affairs (DEFRA, 2009) refers to short-haul flights as those which are typically up to 3700 km in length. This is in broad agreement with the definition proposed by Jardine (2005) who classifies short-haul flights as those less than 3500 km. In contrast, the definition of short-haul air travel adopted in North America suggests a travel distance of around 500 km. For example, the World Resources Institute (WRI) classifies short-haul flights as those of less than 452 km in length (Clean Air Conservancy, 2010). These figures correspond to the definition of regional or domestic flights when applied in the European context (DEFRA, 2010).

Intermediate definitions are also available. The Clear Sky Climate Solutions (2008), for example, categorize the short-haul flying distance as equal to 900 km. The distance of 1108 km is often used as an estimate for short-haul flights by the UK’s Civil Aviation Authority (DEFRA, 2010). The European Environment Agency (EEA) (EEA, 2007) and Peeters and Schouten (2006) argue that short-haul flights have the maximum distance of 1850-2000 km. These figures are in between the short-haul distance extremes identified in the literature, i.e. 452 and 3700 km. So-called ‘extremely short-haul’ flights, i.e. less than 800 km in length, represent a small share of the total air travel market (Matheys *et al.*, 2008) but make a profound carbon impact per ‘passenger km’ due to the substantial energy requirements and GHG emissions associated with take-off and landing and the use of relatively small aircraft (Egli, 1996 cited Gössling, 2000; Jardine, 2005). Hence, short-haul holiday tours based on destinations located 800-2000 km from the UK are deemed to be the most valid objects for analysis.

2.1. Selection of a suitable short-haul destination for the case study

Analysis shows that Portugal, Spain, Southern France, Italy, countries of Central and Eastern Europe, north of the Maghreb region fulfil the selection criteria of a short-haul travel destination. However, Northern Africa can only be reached from the UK by air and traveling by overland means of transport to Eastern and Central Europe, Italy, Spain and Portugal is not popular with British holidaymakers due to travel time and often inconvenient rail schedules. In contrast, Southern France is easily accessible from the UK by overland means of transportation, especially by frequent high-speed trains. In addition, France in general, and Southern France (Provence) in particular, is one of the most popular holiday destinations with British tourists in Europe (Table 1); hence, it has been selected for analysis. While it is acknowledged that the value of a comparative analysis on the basis of Southern France is limited, the primary goal of this study is to compare the GHG emissions associated with different travel scenarios.

[Insert Table 1 here]

2.1.1. Travel scenarios under review

The travel scenarios considered in this study are presented in Figure 1. These are limited to the most feasible travel alternatives for British tourists holidaying in Southern France. Greater London is the departure/arrival point in the UK for overland transport and London Gatwick Airport is for air travel. London Gatwick Airport is selected because it is the largest airport in the UK for leisure travel (Pels *et al.*, 2009). It is assumed that all surface modes of transportation cross the English Channel by Eurotunnel. Holiday scenarios are based on a family of three (two parents and one child).

[Insert Figure 1 here]

The system boundary for the reviewed holiday tours contains all holiday travel elements starting with the departure of tourists from home to their return, i.e. following the ‘door-to-door’ approach (De Camillis *et al.*, 2010) (Figure 2). The preparatory and ‘after trip’ elements are not considered as their contribution to the total GHG emissions from holidays is deemed to be negligible.

[Insert Figure 2 here]

Holidaymakers are assumed to stay in a hotel in the vicinity of Marseille where a large number of holiday resorts are located (Association of British Travel Organisers to France – ABTOF, 2011). Marseille is also selected due to a good availability of travel alternatives, such as air and train. The duration of stay equal to 7 nights was taken as a basic modeling scenario. This number represents the average duration of holidays undertaken by British tourists in France in 2009 (Office for National Statistics, 2010b). To test how a longer stay at the destination alters the total carbon footprint from holiday travel and the relative carbon intensity of its specific elements, a duration of stay equal to 14 nights was also considered. This longer duration of stay is representative of the holidays undertaken by Britons in Mediterranean destinations (Office for National Statistics, 2010b).

Scenario 1: Travel by car.

The major benefit of traveling to Southern France from the UK by car is the flexibility in choosing the itinerary and places visited en-route. The scenario considered in this review is based on the shortest driving distance from London to Marseille. The shortcoming of this approach is that tourists might use the flexibility of car travel to stop and explore attractions en-route which would result in longer distances driven. Google Maps (2011) calculate the one-way travel distance from London to Marseille as 1236 km; the overall trip duration is estimated as 12.5 hours. Since it is unlikely to cover this distance by car in one go, the scenario suggests one en-route overnight stop in the Paris region. It is also assumed that tourists stay overnight in Paris on the way back to the UK. This intermediate stop then divides the journey into two parts: London – Paris (460 km, approximately 5.5 hours of driving) and Paris – Marseille (776 km, 7 hours). It is acknowledged that this scenario is subjective and that the real-life situation can be different, depending on travel preferences of holidaymakers. This notwithstanding, for a better comparative analysis, similar scenario settings will be applied to the analysis of coach and rail journeys.

Scenario 2: Travel by rail.

Travelling to Southern France from the UK by train is less flexible than traveling by car as holidaymakers are bound to train schedules. This notwithstanding, it is fairly easy to get from London to Marseille by rail due to the frequently operated Eurostar services and high-speed trains in France (for detailed schedules, see Rail Europe, 2011). The shortest one-way distance equates to 1134 km (Distance Calculator, 2011; Google Maps, 2011); the journey lasts approximately 7-8 hours and can therefore be made within a single day. For better comparability of overland travel scenarios, two overnight stays in Paris (one for outbound and one for inbound journey) are included in analysis.

Scenario 3: Travel by coach.

Travelling to Southern France from the UK by coach is most feasible in organised groups and by a pre-booked coach; see, for example, Travel 55 (2010) for some existing holidaymaking options in Provence. As for independent travel, although the Eurolines coach group provides regular scheduled coach services from London to Paris (for detailed schedules, see Eurolines, 2011), there are limited opportunities for coach travel from Paris to Marseille. Hence, this scenario assumes that the journey is made by an organised coach with two overnight stays in the Paris region. The one-way driving distance from London to Marseille is identical to the car scenario and equates 1236 km (Google Maps, 2011).

Scenario 4: Travel by air.

There are a number of direct daily scheduled flights from London Gatwick airport to Marseille Provence airport operated by Ryanair, EasyJet and British Airways. The one-way flying distance is 960 km (Air Routing International, 2011). The carbon footprint from destination travel to and from the airport in Southern France is not estimated due to data availability and because its contribution to the total GHG emissions from holidays is deemed to be small. As tourists are assumed to live in Greater London, the same argument is applied to airport transportation in the UK. Importantly, the estimates of GHG emissions from air travel produced in this study do not include the radiative forcing (RF) effect (see, for example, Grassl and Brockhagen, 2007 for more details). The science behind the RF effect is uncertain (Berners-Lee *et al.*, 2011), and as yet no agreement exists in the literature on the magnitude of RF multiplying coefficient (Forster *et al.*, 2006) with estimates ranging from 1.9 to 4.7 (Grassl and Brockhagen, 2007). It is therefore argued that the RF effect should only be used for a sensitivity analysis, rather than be included in carbon footprint assessments of tourism by default.

Scenario 5: Travel by air with an intermediate change (air + air).

This scenario considers traveling to Southern France by air with an intermediate change in Paris. The one-way flying distance is 960 km (Air Routing International, 2011) where the itinerary London – Paris is 307 km and Paris – Marseille – 653 km. While it is arguably not the most popular holidaymaking scenario, it is included in analysis to demonstrate the carbon intensity of air travel interchange. It can be relevant, for example, for holiday journeys from Scotland to continental Europe where no direct flights to the destination exist. Large amounts of GHG emissions are envisaged from this scenario as it involves two flights with consequent significant carbon footprint associated with two take-off and two landing cycles. Moreover, the itinerary London – Paris falls into the category of ‘regional’ flights which are traditionally more carbon intense than any other flights (Jardine, 2005; Koroneos *et al.*, 2005). Another reason for considering this scenario is to better understand the role of airline hubs in the total carbon footprint from flying. This is because flying to the destination may often involve transferring tourists in a hub which implies additional GHG emissions due to take-off and landing. This scenario includes two overnight stays in Paris but it is acknowledged that such a journey scenario can also exclude those.

There are various ‘combined’ scenarios which could have also been used for analysis in this study. For example, train from London to Paris and then coach to Marseille, coach from London to Paris and then train to Marseille, train or coach from London to Paris and then plane to Marseille, or plane from London to Paris and then train to Marseille. However, these are excluded from analysis as it is argued that such travel scenarios, though theoretically possible, are less popular in reality due to potential cost, time and personal comfort concerns.

2.2. Carbon footprint assessment method

Although the necessity to produce reliable estimates of the contribution made by different tourism products and services to the global GHG emissions has been repeatedly emphasized (Cole and Sinclair, 2002; Gössling *et al.,* 2005; Patterson and McDonald, 2004), the literature acknowledges the immaturity of existing techniques for carbon impact assessment of holiday travel (Berners-Lee *et al.,* 2011; Bode *et al.,* 2003). The available methods are small in number and have significant shortcomings which affect the accuracy of appraisals (Filimonau *et al.,* 2011b; Schianetz *et al.,* 2007). The need to advance existing and to develop new, more rigorous approaches to carbon footprint appraisal in tourism is well recognised (Berners-Lee *et al.,* 2011; Collins *et al.,* 2009; Schianetz *et al.,* 2007). The primary drawback of existing methods for carbon impact assessment in tourism is their inability to produce comprehensive estimates of GHG emissions, accounting for both the direct, or operational, and the 'indirect', or embodied, life cycle-related carbon footprints. Empirical studies have shown that the magnitude of the hidden 'indirect' GHG emissions from tourism can be significant (Filimonau *et al.,* 2011c; Patterson and McDonald, 2004; Rosenblum *et al.,* 2000). This emphasizes the necessity to integrate the 'indirect' carbon impacts into existing assessments, thus making them more accurate and truly holistic.

Efforts have begun to address the need for more rigorous carbon footprint appraisal in tourism. The GHG conversion factors produced by DEFRA, which can be employed to estimate the carbon intensity of tourism products and services, are now capable of assessing the 'indirect' GHG emissions embodied in the fuel chain (DEFRA, 2010). Despite this significant methodological improvement, the method by DEFRA is currently unable to address another important dimension of the 'indirect' carbon footprint, the GHG emissions embodied in the non-fuel chain-related capital goods and infrastructure. In the case of coach travel, for instance, these arise from the industrial processes required to extract, transport and refine the raw materials, manufacture a coach, deliver it to a final user and dispose of it (Filimonau *et al.,* 2011c; Frischknecht *et al.,* 2007). This 'indirect' carbon footprint also stems from the renovation, refurbishments and maintenance processes and can be significantly magnified by the tourism supply chain industries (Frischknecht *et al.,* 2007; Patterson and McDonald, 2004; Rosenblum *et al.,* 2000). The contribution of the capital goods and infrastructure to the total carbon impact from tourism products and services can be large (Frischknecht *et al.,* 2007; Potter, 2003 cited Chapman, 2007; Spielmann *et al.,* 2008). The estimates of the 'indirect' carbon footprint produced by DEFRA are therefore incomplete.

The 'indirect' GHG emissions from the capital goods and infrastructure can be appraised by the Life Cycle Assessment (LCA) method, a well-recognized technique for evaluating the environmental impacts from individual products or services throughout their life cycle (Patterson and McDonald, 2004). LCA is acknowledged as the most holistic approach to impact assessment in different industries (Arena and de Rosa, 2003; Frischknecht and Rebitzer, 2005; Junnila, 2004; Ness *et al.,* 2007). Its appraisal methodology has been approved by the International Organisation for Standardization (ISO) and is now reflected in ISO 14040 series of standards (ISO, 2006). Recently, the scope of LCA application has been extended to tourism (Berners-Lee *et al.,* 2011;De Camillis *et al.*, 2010; Filimonau *et al.*, 2011a; Patterson and McDonald, 2004) although the studies are still limited in number and geography (Schianetz *et al.*, 2007).

Despite the comprehensiveness of analysis, the LCA technique has a number of functional limitations and methodological inconsistencies which hamper the accuracy of its estimates. LCA makes assessments of GHG emissions on the basis of extensive life cycle inventories (Koroneos *et al.,* 2005), such as the Ecoinvent database (Frischknecht and Rebitzer, 2005), produced by specialized research groups for a broad range of products and services. The content of the Ecoinvent database enables inclusion or exclusion of the 'indirect', capital goods and infrastructure-related, carbon impacts from analysis (Frischknecht *et al.*, 2007). Although the Ecoinvent database can provide a valuable insight into the life cycle GHG emissions from products and services, it suffers from irregular updates. Furthermore, the background information on how the appraisals are made is often missing. This hampers a critical independent review of the calculation assumptions employed in the LCA estimates (Filimonau *et al.,* 2011c). Lastly, the LCA method employs the definition of short-haul flights which follows the North American classification (see section 2.1.1). This entails overestimation of the actual carbon impacts when the LCA technique is applied to short-haul intra-European flights appraised on a 'per passenger km' basis. In contrast, these drawbacks are less typical of the method by DEFRA which follows the European categorization of short-haul flights, is annually updated to account for the latest advancements in energy and fuel technologies and provides free public access to the background data and assumptions employed.

Given that the GHG conversion factors from DEFRA have a number of critical advantages over the method by LCA, Filimonau *et al.* (2011c) argue that they are more suitable for carbon impact assessment in tourism in terms of the overall accuracy of estimates of the direct carbon footprint and cost-effectiveness. However, in order to obtain the most *holistic* appraisals of carbon impacts, they need to be supplemented with the estimates of the 'indirect' GHG emissions embodied in the tourism capital goods and infrastructure. These can be extracted from the Ecoinvent database. The resultant hybrid values of carbon intensity represent the most accurate and holistic estimates of the carbon footprint as they are capable of appraising the direct and the maximum extent of the 'indirect' GHG emissions from tourism products and services. Filimonau *et al.* (2011c) and Norwegian household carbon calculator (2010) refer to this method of carbon impact assessment as a hybrid, DEFRA-LCA (Ecoinvent) approach. The hybrid method is applied for analysis in this study in order to achieve the highest accuracy of estimates and to demonstrate the share of the 'indirect' carbon footprint in the total GHG emissions from different holiday travel scenarios to Southern France.

2.2.1. The carbon intensity of different elements of holiday travel to Southern France

To assess the magnitude of the carbon footprint attributed to different holiday travel scenarios to Southern France, the carbon intensity coefficients were derived. In the case of transport these comprised of both direct and ‘indirect’ GHG emissions obtained from the database of GHG conversion factors developed by DEFRA (operational carbon footprint + fuel production-related GHG emissions) and further supplemented with the data from the LCA database Ecoinvent (Table 2). Ecoinvent provided estimates of the ‘indirect’ GHG emissions attributed to the 1) non-operational stages of vehicle lifecycle and 2) manufacture, transportation, installation, maintenance and disposal of transport infrastructure.

[Insert Table 2 here]

To appraise the carbon intensity of the hotel stay at the destination and en-route, the GHG emission coefficients for tourist accommodation were derived from the literature as direct measurements of energy consumption in hotels in Southern France and Paris region were not feasible. The value of 9.7 kg of CO_2-eq. per guest night (where 2.4 kg of CO_2-eq. are the ‘indirect’ GHG emissions) was estimated by Filimonau *et al.* (2011c) for the hotel stay in a modern seaside resort in Portugal. As Southern France is a similar Mediterranean sun-and-sand destination, it is argued that the carbon intensity of tourist accommodation is similar to Portugal. This figure is lower than the estimates of carbon intensity of the hotel stay found in other studies (see, for example, CarbonNeutral Company, 2008 cited Chenoweth, 2009; Chan and Lam, 2002; Gössling, 2002), where the values ranging from 14 to 33 kg of CO_2-eq. per guest night were reported (Filimonau *et al.*, 2011a). However, many of these studies focused on the hotels located in the UK and Hong Kong; hence, their estimates need to be taken with caution when applied to other geographies. The carbon intensity of the hotel stay in France is lower than in the UK and Hong Kong due to the larger share of nuclear power in the national energy balance. It is therefore argued that the lower value of 9.7 kg of CO_2-eq. per guest night as estimated by Filimonau *et al.* (2011c) is more suitable for this study. It is also acknowledged that the estimate of the GHG emissions from the hotel stay utilised in this research represents the lower range of the possible carbon footprint range attributable to tourist accommodation.

The literature acknowledges that carbon impact assessment of tourist activities is difficult (Becken and Simmons 2002), mainly due to their diversity and issues with data collection, systematization and further generalisation (Acott *et al.*, 1998). Concurrently, the share of tourist activities in the total carbon footprint from tourism is estimated as minor, 3-5% (UNWTO, 2007). As direct measurements of the GHG emissions from tourist activities in Southern France were not feasible, the study employed the figures retrieved from the literature. This approach is justified given the small carbon contribution of tourist activities in comparison to other elements of holiday travel.

Filimonau *et al.* (2011c) suggest that the average carbon intensity of tourist activities undertaken by holidaymakers during the 7-night stay in a seaside resort in Portugal equates to 16.9 kg of CO_2-eq. This value represents the amount of GHG emissions attributed to the average number of tourist activities undertaken by 43 holidaymakers who were interviewed during their stay. Tourists provided information on the number and type of tourist activities they undertook which were further converted into GHG emissions by using carbon intensity coefficients attributed to each tourist activity type. These were extracted from the literature. As averaged, the analyzed tourist activities included: 2 beach visits, 1 holiday park visit, 1 shopping trip and 2 restaurant visits. This provides a general illustration of the typical activities undertaken by tourists. The estimate also accounted for the carbon footprint produced as a result of travel related to tourist activities, namely 33 km driven by hired car, 35 km by coach, 21 km by bus and 14 km by taxi. Concurrently, Gössling *et al.* (2005) argue that 40 kg of CO_2 can be served as a well-approximated measure of the carbon intensity of tourist activities. However, this latter estimate has a number of limitations. First, it is unclear how the number was obtained and what duration of stay it was based upon. Second, it represents a geographical region with more similar climatic conditions to Southern France. Hence, the figure from Filimonau *et al.* (2011c) is more suitable for this research.

Importantly, the carbon footprint appraisal of tourist activities conducted in this study cannot be considered holistic. First, the holiday trip to Southern France includes two overnight en-route stays in some travel scenarios. Tourist activities undertaken en-route may enhance the carbon intensity of tourist activities reviewed in this study. Second, unlike tourist transport and accommodation, the estimates of the carbon intensity attributed to tourist activities did not take into account the 'indirect' GHG emissions stemming from the fuel chain and capital goods and infrastructure. As the relative contribution of tourist activities to the total carbon footprint from holiday travel is low, the exclusion of their 'indirect' carbon footprint should not make a noticeable effect on the assessment results.

3. Results and discussion

A comparative analysis demonstrates that, under the specified travel settings, going on holiday to Southern France by train or coach are the most carbon-efficient travel options (Figure 3). They produce less than half of the GHG emissions from car and air travel. This is in line with findings from Becken (2001), Brand and Boardman (2008) and Zachariadis and Kouvaritakis (2003) who all identified trains and coaches as having from low to medium energy and carbon intensities compared to other transportation modes. Among these, rail is the least carbon intense scenario in the case study under review. Given that travelling from London to Marseille by train is fairly comfortable, quick and can attract some tourists by (at least) two overnight stays in Paris, it is argued that train is the most viable sustainable alternative to other means of transport for holidaymaking by Britons in Southern France. Travel by coach is another carbon-efficient option which can be a feasible alternative if made in organised groups or for environment-aware tourists with limited budgets.

[Insert Figure 3 here]

Figure 3 shows that the air travel-based holidays in Southern France generate the largest carbon impacts, especially when air + air scenario is considered. This finding is in line with existing knowledge that flying is the most carbon intense means of travel (Becken, 2001; Hanandeh, 2013; Peeters *et al.*, 2006). Importantly, the GHG emissions from the air-based scenario (with no intermediate change) are only circa 15 kg of CO_2-eq. (about 4%) higher than the carbon footprint from the car scenario. The high carbon intensity of the car-based tours is an interesting finding, especially given that such a significant amount of GHG emissions is produced by car journeys with a high (n=3) occupancy. Long distances driven by car are deemed to be the primary reason.

When the relative carbon footprint from holiday travel elements is analyzed, the estimates suggest that transport holds the dominant share only in the car and air travel-based scenarios, i.e. 71% and 77% (81% in the case of the air + air scenario), respectively. In the coach scenario its contribution drops to 43%, while the role of the transport element in the rail scenario is only 35%. This is in agreement with Peeters *et al.* (2006) and Chenoweth (2009) who reported similar patterns. This finding suggests that, tourists willing to cut the GHG emissions from short-haul holidays will achieve the most significant carbon savings with a modal shift from air and car travel. The positive effect of this solution will be high, even if no carbon mitigation measures are applied at the destination, but it is subject to the feasibility of the surface transport alternatives.

Figure 4 shows how the relative share of the transport element in the total GHG emissions from holidaying in Southern France falls when ‘a longer duration of stay at the destination’ scenario is applied. If tourists stay at the destination for 14 nights, transportation contributes 65% (73%), 59%, 31% and 24% to the air travel (air + air scenario), car, coach and rail-based scenarios, respectively. The values will further reduce, should more activities be undertaken by tourists at the destination and/or more intermediate hotel stays be organised en-route. First, Figure 4 does not assume that tourists staying at the destination longer may take part in activities more often or undertake a range of activities with greater carbon footprints. Becken (2008) argues that tourists staying at the destination longer have a tendency not only to partake in tourist activities more often, but also to undertake tourist activities with larger carbon intensities. Likewise, Filimonau *et al.* (2011c) finds that tourists begin to engage in more energy-intense activities with a longer duration of stay. This argument is particularly valid when considering a ‘travel by car’ scenario for tourists staying at the destination for 14 nights. Given the flexibility of this travel option and long duration of stay, holidaymakers might use a car to explore the surroundings in Southern France. This would enhance the carbon intensity of the destination-based elements of holiday travel. Second, existing holiday tours to Southern France often incorporate additional overnight stays and excursions in the Champagne region; see Travel 55 (2010) for more details. All this implies that, under certain travel scenarios and holidaymaking settings, the traditional standpoint which considers transport to/from the destination as a primary contributor to the total GHG emissions from holidays can be questioned. This review suggests that the non-transit elements of holiday travel can have a significant share in the total carbon footprint from short-haul holidays, especially when tourists travel to the destination by overland public transport. They should not therefore be ignored in the GHG emission assessments of holiday travel and need to be considered when developing and evaluating the carbon impact mitigation measures for holiday packages.

[Insert Figure 4 here]

When the estimates of GHG emissions are made on a 'daily' basis, the analysis suggests that a longer stay in Southern France reduces the daily carbon intensity of the holiday (Table 3). The magnitude of reduction varies depending on the method of transportation to/from the destination. The daily carbon intensity of the longer stay is circa 70-80% less than of the shorter stay for such transport modes as air travel and car. For surface public means of transportation the discrepancy is less significant, 40-45%. This finding is in broad agreement with the literature which considers a longer stay at the destination more beneficial in the eco-efficiency terms if the estimates are made on a daily basis (Gössling *et al.*, 2005; Peeters *et al.*, 2006).

[Insert Table 3 here]

Lastly, Figure 5 demonstrates that the 'indirect' GHG emissions make a profound contribution to the total carbon footprint from holiday travel to Southern France. The air travel and car scenarios are characterised by the largest 'indirect' carbon shares of circa 25-30%, while the other scenarios demonstrate lower, but yet significant, values of 15-20%. Most of the 'indirect' GHG emissions are attributed to the transportation element. The largest contribution of the 'indirect' GHG emissions *within the transportation element* of holiday travel was established for rail (about 40%), while the lowest - for coach travel (approximately 25%). This is in broad agreement with Spielmann *et al.* (2008) who found that the largest share of the 'indirect' GHG emissions is typically attributed to train (with the magnitude of up to 60% of the total carbon footprint) while the lowest (up to 20%) – to coach and bus travel. This finding has important implications for transport and environmental policy-makers. While rail is commonly considered as the most carbon-efficient transportation option, the holistic analysis of its carbon impacts shows that its advantage is reduced marginally when the 'indirect' carbon requirements are taken into account. All this emphasizes the necessity to include the estimates of the 'indirect' GHG emissions into carbon footprint assessments of tourism in general and holiday packages in particular.

[Insert Figure 5 here]

The findings have important implications for the emerging concept of slow travel. Within Europe, slow travel is largely conceptualised as a form of tourist travel that involves a greater engagement with the transport element of tourism and with the places visited en-route (Dickinson and Lumsdon, 2010). Slow travel avoids air and car journeys and embraces travel by train, coach, bus, bicycle and on foot. A slow travel strategy therefore offers a lower carbon tourism option since carbon footprint mitigation strategies should focus primary on reducing air and car travel. On the other hand, this research indirectly demonstrated that such variables as the number of overnight hotel stays/travel interchanges, staying in energy-inefficient tourist accommodation and partaking in energy-intense activities en-route may significantly increase the carbon footprint of travel to/from the destination. Therefore, in a slow travel scenario, mitigation strategies should focus on accommodation and activity elements. This finding also suggests that a comprehensive analysis of the carbon intensity of different travel scenarios is crucial for designing holiday tours with the smallest carbon impact.

4. Conclusions

The critical analysis of the literature on carbon footprint assessment of tourism indicates that the transport (transit) element of holiday travel is traditionally considered as the primary contributor to its total GHG emissions, while the share of the non-transit, destination-based elements is conventionally accepted as low. A few studies have challenged this standpoint in relation to short-haul holiday travel but provided no consistent, detailed analysis of different travel scenarios to a popular holiday destination. Moreover, the outcome of these studies suffers from the limited accuracy and comprehensiveness of evaluation. This is because the traditional methods employed for carbon impact appraisal in tourism fail to account for the complexity of the GHG emissions which include not only the direct, or operational, but also the 'indirect', or embodied in the non-operational stages of a product or service lifecycle, carbon footprint. Existing studies from outside of tourism argue this 'indirect' carbon contribution is significant.

This research aimed to rectify these knowledge gaps by applying a critical scenario analysis to different travel alternatives for holidaying in Southern France, a popular short-haul tourist destination with Britons. It demonstrated how the choice of transportation to/from the short-haul holiday destination might affect the total carbon footprint from holidays. The results indicate that flying and driving a car are the most carbon-intense means of travel to Southern France, while traveling to the destination by train and coach produce significantly lower amounts of GHG emissions. This suggests that a modal shift in transportation should be the primary measure for carbon footprint reduction in tourism to this destination. The research contributed to better understanding of the role played by airline hubs in the carbon footprint from holiday travel. Transferring tourists in a hub almost doubles the GHG emissions from transportation to/from the destination for the case study under review if compared to a single, direct flight. This suggests that tour operators should avoid travel interchanges in airline hubs when designing holiday tours with low carbon footprint.

The study showed that the non-transit elements of holiday travel can make a noticeable, and even dominant, contribution to the total carbon footprint from short-haul holidays. Traveling to/from the destination by public overland transport and a longer stay at the destination are the primary variables which enhance the carbon significance of the non-transit elements. This finding clashes with the conventional perception of the relative carbon intensity of different elements of holiday travel which overstates the dominant share of transportation. It suggests that policy-makers and tour operators should not ignore the non-transit elements of holidays when developing and evaluating carbon footprint mitigation measures for short-haul holiday tours. Therefore, while the primary target of carbon footprint mitigation should be reducing air and car travel, important carbon savings can be made with respect to accommodation and activities. To minimize the carbon intensity of non-transit elements of holiday travel, tour operators may impose additional carbon-related requirements on hotels, thus encouraging hoteliers to adapt carbon mitigation measures. Tour operators can, for example, build holiday tours around eco-certified accommodation facilities and/or demand external carbon performance appraisals from their contractors.

The research showed that the longer stay at the destination will increase the *absolute* amount of GHG emissions from short-haul holiday travel. However, when the carbon footprint from holidays in Southern France is assessed on a daily basis, the estimates demonstrate that the longer stay is more beneficial, thus identifying another carbon impact mitigation opportunity. The shortcoming of this study is however that it did not evaluate the economic impacts imposed by tourists with different durations of stay at the destination which outlines an avenue for further research.

It is argued that the implications of traveller's age, class, family structure and personal interests may play an important role in the carbon intensity of holiday travel as any personal decisions on selection of specific travel modes, types of accommodation and tourist activities during a holiday tour are difficult to predict. This role requires better understanding. To produce reliable estimates of GHG emissions from holiday travel in general and tourist activities in particular, accurate records of actual tourists' behaviour are necessary. Tour operators can help address this task by working with researchers to compile appropriate data. It is argued that travel diaries and surveys may add the necessary precision and context to the data required for holistic carbon footprint assessments of holiday tours.

Lastly, this study provided more empirical evidence of the applicability of a new, more advanced method for carbon footprint assessment in tourism. This hybrid, DEFRA-LCA approach incorporates the advantages of existing techniques for carbon impact appraisal and generates more accurate and holistic estimates by accounting for the 'indirect' GHG emissions. The analysis indicated that the 'indirect' carbon requirements play an important role in the total carbon footprint from holidaying in Southern France. Such popular means of transportation as air travel and car were found to have the largest shares of the 'indirect' GHG emissions, circa 25-30%. These hidden carbon emissions would have been excluded from analysis, should the estimates have been based on conventional methods for carbon impact assessment in tourism. This suggests that many of the existing estimates of GHG emissions from holiday travel are likely to underestimate its actual carbon footprint. It also underlines the necessity to account for the 'indirect' carbon requirements of tourism when conducting environmental assessments of its impacts and when developing and appraising prospective carbon footprint mitigation strategies.

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Notes

1. The estimates of the ’indirect’ GHG emissions for 14 nights of stay in Southern France are not presented. This is because the only difference would be the additional ‘indirect’ carbon footprint from a longer hotel stay at the destination which equates to about 17 kg of CO_2-eq. for additional 7 nights.

References

ABTOF - Association of British Travel Organisers to France, 2011. *Holiday France.* Available at: http://holidayfrance.org.uk/index.aspx. Accessed 24.02.2012.

Acott, T. G., La Trobe, H.L., Howard, S.H., 1998. An evaluation of deep ecotourism and shallow ecotourism. *Journal of Sustainable Tourism,* 6 (3), 238-253.

Air Routing International, 2011. Time and distance calculator (great circle). Available at: http://www.airrouting.com/content/TimeDistanceForm.aspx. Accessed 15.06.2011.

Arena, A. P., and De Rosa, C., 2003. Life cycle assessment of energy and environmental implications of the implementation of conservation technologies in school buildings in Mendoza - Argentina. *Building and Environment,* 38 (2), 359-368.

Becken, S., 2001. *Tourism and transport in New Zealand: implications for energy use.* Tourism Recreation Research and Education Centre (TRREC) report No. 54. Lincoln University, July 2001

Becken, S., 2002. Analysing international tourist flows to estimate energy use with air travel. *Journal of Sustainable Tourism,* 10 (2), 114-131.

Becken, S., 2008. Developing indicators for managing tourism in the face of peak oil. *Tourism Management,* 29 (4), 695-705.

Becken, S., and Patterson, M., 2006. Measuring national carbon dioxide emissions from tourism as a key step towards achieving sustainable tourism. *Journal of Sustainable Tourism,* 14 (4), 323-338.

Becken, S., and Simmons, D. G., 2002. Understanding energy consumption patterns of tourist attractions and activities in New Zealand. *Tourism Management,* 23 (4), 343-354.

Becken, S., Simmons, D. G., and Frampton, C., 2003. Energy use associated with different travel choices. *Tourism Management,* 24 (3), 267-277.

Berners-Lee, M., Howard, D. C., Moss, J., Kaivanto, K., and Scott, W. A., 2011. Greenhouse gas footprinting for small businesses - the use of input-output data. *Science of the Total Environment,* 409 (5), 883-891.

Bode, S., Hapke, J., and Zisler, S., 2003. Need and options for a regenerative energy supply in holiday facilities. *Tourism Management,* 24 (3), 257-266.

Brand, C., and Boardman, B., 2008. Taming of the few - the unequal distribution of greenhouse gas emissions from personal travel in the UK. *Energy Policy,* 36 (1), 224-238.

Byrnes, T. A., and Warnken, J., 2006. Greenhouse gas emissions from marine tours: a case study of Australian tour boat operators. *Journal of Sustainable Tourism,* 14 (3), 255-270.

Chan, W. W., and Lam, J.C., 2002. Prediction of pollutant emission through electricity consumption by the hotel industry in Hong Kong *Hospitality Management,* 21, 381-391.

Chapman, L., 2007. Transport and climate change: a review. *Journal of Transport Geography,* 15 (5), 354-367.

Chenoweth, J., 2009. Is tourism with a low impact on climate possible? *Worldwide Hospitality and Tourism Themes,* 1 (3), 274-287.

Clean Air Conservancy, 2010. NETZERO Air Travel Calculator. Available at: http://www.cleanairconservancy.org/calculator_air.php. Accessed 04.08.2010.

Clear Sky Climate Solutions, 2008. Carbon Footprint Calculator. Available at: http://www.clearskyclimatesolutions.com/calculator.html. Accessed 05.08.2010.

Cole, V., and Sinclair, A. J., 2002. Measuring the ecological footprint of a Himalayan tourist center. *Mountain Research and Development,* 22 (2), 132-141.

Collins, A., Jones, C., and Munday, M., 2009. Assessing the environmental impacts of mega sporting events: Two options? *Tourism Management,* 30 (6), 828-837.

De Camillis, C., Raggi, A., and Petti, L., 2010. Tourism LCA: state-of-the-art and perspectives. *International*

Journal of Life Cycle Assessment, 15 (2), 148-155.

DEFRA - Department for Environment, Food and Rural Affairs, 2009. *2009* Guidelines to DEFRA / DECC's GHG conversion factors for company reporting. Version 2.0. Available at: http://www.defra.gov.uk/environment/business/reporting/pdf/20090928-guidelines-ghg-conversion-factors.pdf. Accessed 18.12.2009.

DEFRA - Department for Environment, Food and Rural Affairs, 2010. 2010 Guidelines to DEFRA / DECC's GHG conversion factors for company reporting. Available at: http://www.defra.gov.uk/environment/business/reporting/pdf/101006-guidelines-ghg-conversion-factors.pdf. Accessed 13.05.2011.

Dickinson, J. and Lumsdon, L., 2010. *Slow travel and tourism.* Earthscan, London, UK.

Distance Calculator, 2011. Distance calculator. Measure the distance from A to B. Available at: http://www.distance-calculator.co.uk/. Accessed 28.11.2011.

Dolnicar, S., Laesser, C., and Matus, K., 2010. Short-haul city travel is truly environmentally sustainable. *Tourism Management*, 31 (4), 505-512.

EEA - European Environment Agency, 2007. *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook. Technical Report 16/2007. Index to methodology chapters – Group 8, Other mobile sources and machinery*. Copenhagen: European Environment Agency (EEA), 2007.

Eurolines, 2011. Eurolines. Coach travel across the Europe from the UK. Available at: http://www.eurolines.co.uk/coach/index.aspx. Accessed 22.02.2011.

Filimonau, V., Dickinson, J. E., Robbins, D., and Huijbregts, M. A. J., 2011a. Reviewing the carbon footprint analysis of hotels: Life Cycle Energy Analysis (LCEA) as a holistic method for carbon impact appraisal of tourist accommodation. *Journal of Cleaner Production*, 19 (17-18), 1917-1930.

Filimonau, V., Dickinson, J. E., Robbins, D., and Reddy, M. V., 2011b. A critical review of methods for tourism climate change appraisal: life cycle assessment as a new approach. *Journal of Sustainable Tourism*, 19 (3), 301-324.

Filimonau, V., Dickinson, J. E., Robbins, D., Reddy, M. V., 2011c. The role of 'indirect' greenhouse gas emissions in tourism: assessing the hidden carbon impacts. *Submitted to Journal of Transportation Research Part A: Policy and Practice.*

Forster, P. M. D., Shine, K. P., and Stuber, N., 2006. It is premature to include non-CO_2 effects of aviation in emission trading schemes. *Atmospheric Environment*, *40 (6)*, 1117-1121.

Frischknecht, R., Althaus, H. J., Bauer, C., Doka, G., Heck, T., Jungbluth, N., Kellenberger, D., and Nemecek, T., 2007. The environmental relevance of capital goods in life cycle assessments of products and services. *International Journal of Life Cycle Assessment*, 12, 7-17.

Frischknecht, R., and Rebitzer, G., 2005. The Ecoinvent database system: A comprehensive web-based LCA database. *Journal of Cleaner Production*, 13 (13-14), 1337-1343.

Google Maps, 2011. Google maps. Available at: http://maps.google.co.uk/. Accessed 23.11.2011.

Gössling, S., 2000. Sustainable tourism development in developing countries: some aspects of energy use. *Journal of Sustainable Tourism*, 8 (5), 410-425.

Gössling, S., 2002. Human-environmental relations with tourism. *Annals of Tourism Research*, 29 (2), 539-556.

Gössling, S., 2009. Carbon neutral destinations: a conceptual analysis. *Journal of Sustainable Tourism*, 17 (1), 17-37.

Gössling, S., Hansson, C. B., Horstmeier, O., and Saggel, S., 2002. Ecological footprint analysis as a tool to assess tourism sustainability. *Ecological Economics*, 43 (2-3), 199-211.

Gössling, S., and Peeters, P., 2007. "It does not harm the environment!" An analysis of industry discourses on tourism, air travel and the environment. *Journal of Sustainable Tourism*, 15 (4), 402-417.

Gössling, S., Peeters, P., Ceron, J. P., Dubois, G., Patterson, T., and Richardson, R. B., 2005. The eco-efficiency of tourism. *Ecological Economics,* 54 (4), 417-434.

Grassl, H., and Brockhagen, D., 2007. *Climate forcing of aviation emissions in high altitudes and comparison of metrics. An update according to the fourth assessment report, IPCC 2007.* Hamburg, Germany: Max Planck Institute for Meteorology, December 2007.

Hanandeh, A.E., 2013. Quantifying the carbon footprint of religious tourism: the case of Hajj. *Journal of Cleaner Production,* in press, accepted manuscript.

Hunter, C., 2002. Sustainable tourism and the touristic ecological footprint. *Environment, Development and Sustainability,* 4, 7-20.

Hunter, C., and Shaw, J., 2007. The ecological footprint as a key indicator of sustainable tourism. *Tourism Management,* 28 (1), 46-57.

ISO - International Organization for Standardization, 2006. *ISO 14040:2006, Environmental Management – Life Cycle Assessment – Principles and Framework.* ISO, Geneva, Switzerland, 2006.

Jardine, C.N., 2005. *Calculating the environmental impact of aviation emissions. Part 1.* Environmental Change Institute, Oxford University Centre for the Environment, Oxford, UK, June 2005.

Junnila, S., 2004. The environmental significance of facilities in service sector companies. *Facilities,* 22 (7/8), 190-198.

Koroneos, C., Dompros, A., Roumbas, G., and Moussiopoulos, N., 2005. Advantages of the use of hydrogen fuel as compared to kerosene. *Resources Conservation and Recycling,* 44 (2), 99-113.

McKercher, B., Prideaux, B., Cheung, C., and Law, R. 2010. Achieving voluntary reductions in the carbon footprint of tourism and climate change. *Journal of Sustainable Tourism*, 18(3), 297-317.

Matheys, J., Festraets, T., Timmermans, J-M., Sergeant, N., Van Mierlo, J., 2008. Alternative road vehicles, electric rail systems, short flights: an environmental comparison. *The World Electric Vehicle Journal,* 2 (4), 1-6.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., and Olsson, L., 2007. Categorising tools for sustainability assessment. *Ecological Economics,* 60 (3), 498-508.

Norwegian household carbon calculator, 2010. Klimakalkulatoren ved Klimaloftet. Available at: http://klimakalkulatoren.no/media/2382/bakgrunnstall_til_klimakalkulator_201010.pdf. Accessed 16.11.2010.

Office for National Statistics, 2010a. *Quarterly Overseas Travel and Tourism. Quarter 4 2010.* Office for National Statistics, Newport, UK. Available from: http://www.statistics.gov.uk/downloads/theme_transport/mq6-overseas-travel-2010-q4.pdf [Accessed 23 June 2011].

Office for National Statistics, 2010b. Travel trends 2009. Available at: http://www.ons.gov.uk/ons/rel/ott/travel-trends/2009/travel-trends---travel-trends---a-report-on-the-international-passenger-survey.pdf. Accessed 06.10.2011.

Patterson, M. G., and McDonald, G., 2004. *How clean and green is New Zealand tourism? Lifecycle and future environmental impacts.* Lincoln, N.Z.: Manaaki Whenua Press.

Patterson, T. M., Niccolucci, V., and Bastianoni, S., 2007. Beyond "More is better": ecological footprint accounting for tourism and consumption in Val Di Merse, Italy. *Ecological Economics,* 62 (3-4), 747-756.

Peeters, P., Gössling, S., Becken, S., 2006. Innovation towards tourism sustainability: climate change and aviation. *International Journal of Innovation and Sustainable Development,* 1 (3), 184-200.

Peeters, P., and Schouten, F., 2006. Reducing the ecological footprint of inbound tourism and transport to Amsterdam. *Journal of Sustainable Tourism,* 14 (2), 157-171.

Peeters, P., Szimba, E., and Duijnisveld, M., 2007. Major environmental impacts of European tourist transport. *Journal of Transport Geography,* 15 (2), 83-93.

Pels, E., Njegovan, N., Behrens, C., 2009. Low-cost airlines and airport competition. *Transportation Research Part E: Logistics and Transportation Review,* 45(2), 335-344.

Rail Europe, 2011. European train tickets. Available at: http://www.raileurope.co.uk/. Accessed 22.02.2011.

Rosenblum, J., Horvath, A., and Hendrickson, C., 2000. Environmental implications of service industries. *Environmental Science & Technology*, 34 (22), 4669-4676.

Schianetz, K., Kavanagh, L., and Lockington, D., 2007. Concepts and tools for comprehensive sustainability assessments for tourism destinations: A comparative review. *Journal of Sustainable Tourism*, 15 (4), 369-389.

Spielmann, M., De Haan, P., and Scholz, R. W., 2008. Environmental rebound effects of high-speed transport technologies: A case study of climate change rebound effects of a future underground Maglev train system. *Journal of Cleaner Production*, 16 (13), 1388-1398.

Susilo, Y. O. and Stead, D., 2009. Individual Carbon Dioxide Emissions and Potential for Reduction in the Netherlands and the United Kingdom. *Transportation Research Record*, 2139, 142-152.

Travel 55, 2010. Coach holidays. Short breaks by coach. Holidays by coach worldwide. Available at: http://www.travel55.co.uk/index.html. Accessed 22.02.2011.

UNWTO - United Nations World Tourism Organization, 2007. *Climate Change and Tourism: Responding to Global Challenges. Advanced Summary*. Davos, UNWTO, October 2007.

Zachariadis, T., and Kouvaritakis, N., 2003. Long-term outlook of energy use and CO2 emissions from transport in central and eastern Europe. *Energy Policy*, 31 (8), 759-773.