REVIEWING THE CARBON FOOTPRINT ASSESSMENT OF TOURISM: DEVELOPING AND EVALUATING LIFE CYCLE ASSESSMENT (LCA) TO INTRODUCE A MORE HOLISTIC APPROACH TO EXISTING METHODOLOGIES

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ABSTRACT

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Reviewing the carbon footprint assessment of tourism: developing and evaluating Life Cycle Assessment (LCA) to introduce a more holistic approach to existing methodologies

It is universally recognised that, *globally*, the tourism industry is a noticeable contributor to the carbon footprint. The magnitudes of the greenhouse gas (GHG) emissions from specific tourism products and services at *local* levels are less established and large variations in estimates exist. Diversity of the tourism sector, constraints in data procurement and under-development of methods for tourism carbon impact appraisal are the primary reasons. These hinder accurate evaluations and hamper development of reliable carbon performance indicators, thus making direct comparisons between tourism products and services difficult.

The issue of the 'indirect' carbon impacts, additional carbon requirements from the non-use phases of a product or service life cycle, which can be further magnified by the supply chain, is of special concern. These carbon footprints have never been comprehensively assessed in tourism, especially at the level of specific products and services. The evidence from the non-tourism literature suggests that the 'indirect' carbon impacts from tourism-related activities can be high, thus calling for more in-depth research on this issue.

The aim of this study is to contribute to the development of reliable carbon footprint assessment methodologies in tourism. It proposes an approach for more holistic estimates of GHG emissions from tourism products and services and appraises the Life Cycle Assessment (LCA) method whose merit in estimating the 'indirect' carbon impacts is broadly recognised.

The evidence of the application of LCA in tourism is limited. To test the viability of a new technique in the tourism context, the study employs a case study approach and applies a simplified derivative of LCA, Life Cycle Energy Analysis (LCEA), to assess the carbon footprint from a popular tourism product, a holiday package tour. LCEA is compared against existing methodological alternatives for estimating carbon footprints from holiday travel. This is to understand strengths and weaknesses in the LCA (LCEA)

approach, to critically evaluate the new technique compared to the alternatives, and to identify the most accurate and cost-effective method for holistic assessment.

The assessment results demonstrate the importance of the ‘indirect’ GHG emissions in tourism. The findings also show that, despite the new outlook it brings to tourism carbon footprint appraisal, LCEA cannot effectively capture the full range of carbon impacts. This is because a number of methodological inconsistencies affect the accuracy of estimates. As limitations are also typical for the more established methodological alternatives, a new, hybrid LCEA-related assessment approach is developed. It is argued that this hybrid method can address the identified methodological shortcomings, thus representing currently the most rigorous technique for carbon impact appraisal in tourism.

This study does more than reinforcing the methodological base for tourism carbon footprint assessment by developing a new method. It provides recommendations on how to improve the general quality and enhance the reliability of LCA (LCEA) for application in other industries where it has a long-standing tradition of use. Directions are also proposed on how to refine collection of the input data for carbon footprint assessment in tourism, in order to obtain more accurate results and reduce uncertainty in estimates. Last but not least, suggestions are made on how to integrate more carbon-effective practices in the design of specific tourism products and services.

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LIST OF ABBREVIATIONS

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (French Environment and Energy Management Agency)
AI	All-Inclusive
BSI	British Standard Institute
CC	Carrying Capacity
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
EEA	European Environmental Agency
EFA	Ecological Footprint Analysis
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EU	European Union
EUI	Energy Use Index
GFA	Gross Floor Area
GHG	Greenhouse Gas
GHG PI	Greenhouse Gas Protocol Initiative
GPS	Global Positioning System
GWP	Global Warming Potential
HVAC	Heating, Ventilation, Air-Conditioning
ICAO	International Civil Aviation Organisation
ICE	Inter-City Express
IFEU	Institut für Energi und Umweltforschung (Institute of Energy and Environmental Research)
IOA	Input-Output Analysis
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
ITO	Independent Tour Operator
kWh	Kilowatt per Hour
LCA	Life Cycle Assessment
LCEA	Life Cycle Energy Analysis
LPG	Liquefied Petroleum Gas
MIPS	Material Input per Service Unit
MJ	Mega Joule
PAS	Publicly Available Specification

pkm	Passenger (person) kilometre
PLC	Public Limited Company
RAC	Royal Automobile Club
RF	Radiative Forcing
SAS	Statistical Analysis System
SC	Self-Catering
SETAC	Society of Environmental Toxicology and Chemistry
ST CRC	Sustainable Tourism Cooperative Research Centre
TREMOD	Transport Emission Model
TUI	Touristik Union International
UK	United Kingdom
UK CEED	UK Centre for Economic and Environmental Development
UNWTO	United Nations World Tourism Organisation
UNWTO-UNEP--WMO	United Nations World Tourism Organisation-United Nations Environment Programme-World Meteorological Organisation
USA	United States of America
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

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Я вельмі ўдзячны ўсім Вам. Вялікі дзякуй!

AUTHOR'S DECLARATION

In the course of collecting data for this thesis two journal articles have been accepted for publication. These are acknowledged, where appropriate, in the text and listed and included in Appendix 2.

CHAPTER 1. INTRODUCTION

1.1 RESEARCH RATIONALE

The literature acknowledges the immaturity of existing techniques for environmental assessment of tourism impacts (Lundie *et al.* 2007). The available methodologies were originally designed for making environmental appraisals of non-tourism products and services. The scope of their assessments has only recently been extended to tourism. As a result, the potential of these methods to account for the full scale and diversity of environmental impacts from the tourism industry is limited. The literature emphasises the necessity to refine existing and to develop new, more advanced techniques for environmental assessment in tourism (Schianetz *et al.* 2007).

The contribution of the tourism industry to global carbon footprint is well recognised (United Nations World Tourism Organisation - UNWTO 2007) and the appeal to cut its greenhouse gas (GHG) emissions has been documented in a number of international agreements (Davos Declaration 2007; Djerba Declaration 2003). To mitigate the carbon impacts from tourism, the magnitudes of GHG emissions attributed to its specific products and services need to be established. Reliable carbon footprint assessment methods are required to fulfil this task. Surprisingly, a review of literature shows that the number of techniques employed for assessing the carbon impacts from tourism are small, while the quality of the appraisals produced is limited. To advance future assessments, the development of new, more accurate and reliable approaches and improvement of existing methodologies for carbon footprint appraisal in tourism is necessary.

The largest shortcoming of the current techniques for assessing the carbon impacts from tourism is the limited capability for estimating the ‘indirect’, life cycle-related GHG emissions (Gössling 2009; Patterson and McDonald 2004). These stem from the non-use phases of a product or service life cycle, i.e. from industrial processes required to extract raw materials, manufacture tourism products and services and deliver them to the consumer. Maintenance and final disposal also make a contribution to the ‘indirect’ carbon impacts. The ‘indirect’ carbon footprint is, for example, embedded in the capital goods and infrastructure used to support the industrial processes at different stages of a product or service life cycle (see, for example, Frischknecht *et al.* 2007a for detailed discussion). The ‘indirect’ GHG emissions are further magnified by the breadth and diversity of the tourism supply chain. The non-tourism literature reports that the magnitude of the ‘indirect’ carbon footprint from such tourism-related services as leisure transport and accommodation can be high (Frischknecht *et al.* 2007a). It is therefore argued that the exclusion of these 'indirect' contributions from carbon footprint appraisals may result in significant underestimates of the total GHG emissions from tourism. This calls for extending the scope of current assessments, to account for the 'indirect' carbon footprint from tourism products and services.

Existing appraisals of carbon impacts from tourism have primarily focused on the transportation, or transit, element of holiday travel. This is because the literature argues that the destination-based elements, i.e. accommodation and activities, produce relatively small amounts of GHG emissions in comparison to transport (Gössling *et al.* 2002). While fair for long-haul travel, this argument can be questioned in analysis of short-haul travel. This is particularly relevant if tourists travel to the destination by overland public transport and stay there longer. Under the short-haul travel settings, there is also a clash against another popular argument, widespread in the literature, which encourages longer stay at the destination as it is considered beneficial in terms of the relative eco-efficiency (Gössling *et al.* 2005). A few studies have challenged this standpoint (see, for instance, Chenoweth 2009) but provided no critical comparative analysis of different travel scenarios for short-haul holidays, thus calling for more detailed research on this topic.

The limited scale of tourism carbon footprint appraisal is recognised as another issue. The primary focus of existing assessments has been on small, activity-specific, or on large, national or sector-specific, impacts. These are represented by, for example, measurements of the GHG emissions from personal car journeys and national hotel sectors which can also be categorised as the 'micro' and 'macro' levels of appraisals, respectively. Little research exists in between, i.e. on carbon impacts from such popular tourism products as holiday package tours (Hunter 2002).

Holiday package tours make a profound share in many national tourism markets and may correspond to the intermediate, 'meso' level of environmental assessment in tourism. The gap in carbon footprint appraisal of holiday packages is partially due to the methodological difficulties of assessing the carbon intensities of composite tourism products. This issue is closely linked to a poor understanding of the data inputs required for analysis. Holiday package tours consist of a number of different 'micro' or activity-specific elements which can be grouped into tourist transport, tourist accommodation and tourist activities categories. To measure the GHG emissions from the entire holiday package, methodologies for carbon footprint assessment should be capable of estimating the carbon intensities of all of its specific elements. A conceptual framework which would outline a rigorous carbon footprint assessment procedure for holiday package tours, identifying data and labour requirements, is also necessary.

The limited scale of tourism carbon impact assessment has affected selection of units for measuring the GHG emissions from tourism. Estimating the carbon footprint per single tourist is currently not a popular practice in tourism impact assessment (Deng and Burnett 2002) although this unit can be more appropriate for the design of carbon impact mitigation measures at local and regional level. The partial reason for the limited use of the 'per tourist' estimates may stem from a poor understanding of the data required to holistically assess the GHG emissions from individual tourists. It is therefore necessary to demonstrate how the tourist-specific carbon impacts can be measured for different tourism products and services and how the routine collection of basic data needs to be organised for successful carbon footprint assessments of holidays.

Life Cycle Assessment (LCA) is an established technique for holistic environmental appraisal (Junnila 2004). LCA has been broadly used for assessing products and services from many industries, but the evidence of its application in tourism is limited. This represents a promising area for research. The recognised merit of LCA in estimating the ''indirect'', product or service life cycle-related GHG emissions is the primary benefit of applying this technique for carbon footprint assessment in tourism. However, the LCA methodology:

1) has to be developed and/or adapted to suit the needs of tourism carbon impact appraisal;

2) needs to be tested in the tourism domain to demonstrate its potential for holistic carbon footprint assessment of different tourism products and services; and

3) calls for a comparative analysis against traditional carbon footprint assessment tools to find the best tool, or combination of tools, for making the most accurate, cost-effective and comprehensive appraisals of carbon footprint from tourism.

1.2 AIM AND OBJECTIVES

The overall aim of this study is **to enhance the methodological basis for holistic carbon footprint assessment in tourism.**

To achieve this aim, a new method, Life Cycle Assessment (LCA), a well-established technique for holistic appraisal of environmental impacts from products and services, is introduced to tourism. The study adapts and develops the LCA methodology to address the specific needs of tourism carbon footprint assessment research. The applicability of LCA in a tourism context is tested by performing a carbon footprint analysis of a composite tourism product, a standard holiday package tour. The new perspectives added by LCA to the research on carbon impact appraisal in tourism are evaluated. A comparative analysis of LCA against existing methodological alternatives for tourism carbon footprint assessment is conducted. The most accurate and cost-effective techniques for comprehensive appraisal of the carbon footprint from tourism products and services are proposed on the basis of the critical evaluation of the strengths and weaknesses attributed to each of the reviewed approaches. Recommendations are made on how to improve the overall quality of carbon footprint appraisals in tourism and enhance the assessment potential of the reviewed methodologies.

The study aim is to be achieved throughout the fulfilment of the following objectives:

1) To critically evaluate the capability of the key techniques for environmental assessment of tourism impacts to provide accurate and holistic estimates of carbon footprint from tourism products and services;

The key methods for environmental assessment of tourism impacts identified in the literature are reviewed. The strengths and limitations of available approaches are analysed. The issues in appraising the carbon significance of tourism which have been raised, but not fully addressed, by existing assessments are identified and evaluated.

2) To examine the potential of Life Cycle Assessment (LCA) for holistic appraisal of carbon footprint from tourism products, services and activities;

The strengths of LCA and its potential to tackle the issues raised by existing tools are analysed. The topic of the ‘indirect’ carbon footprint in tourism is discussed in depth. The new outlook on a holistic analysis of carbon impacts proposed by LCA is reviewed.

3) To provide empirical evidence of the applicability of LCA in the tourism context by performing a holistic carbon footprint assessment of a short-haul holiday package;

A conceptual framework for comprehensive carbon footprint appraisal of a holiday package is proposed. The case study approach is used to identify the limitations of LCA when applied to tourism and to understand how these limitations can be overcome. The relative carbon significance of all holiday package elements is evaluated. The magnitudes of the 'indirect' carbon impacts are established.

4) To perform a comparative analysis of LCA with existing methodological alternatives for carbon footprint assessment in tourism;

The LCA technique is evaluated against the key available methods with regard to the scope of analysis, accessibility, ease of use, viability of the assumptions employed and background information provided. A critical analysis is applied to identify a carbon footprint appraisal technique, or combination of techniques, which would represent the most accurate and cost-effective methodological approach for the holistic carbon footprint analysis of tourism products and services.

5) To understand what factors affect the total and relative magnitudes of carbon impacts from a short-haul holiday package by applying a sensitivity and scenario analysis;

A sensitivity analysis is employed to demonstrate how different holiday package variables affect its total carbon footprint. The role of assumptions and background information in producing accurate estimates is discussed. Realistic travel scenarios for short-haul holidays are analysed to identify the most carbon-effective practices.

6) To recommend measures for refinement of the reviewed methodologies for carbon impact assessment to enhance the effectiveness of their application in the tourism context.

Measures to enhance the quality of carbon footprint assessment in tourism and to reduce the uncertainty in estimates are proposed. Recommendations to strengthen the methodological rigour of LCA and of alternative techniques for assessing carbon impacts from tourism products and services are made.

1.3. SCOPE AND LIMITATIONS

The limitations of this research are discussed across the text. Some general limitations are outlined below:

Holistic or *comprehensive* environmental assessment is defined in the context of this study as a rigorous analysis of a *single* environmental impact, climate change. This definition implies that the direct (i.e. the operational energy consumption and associated carbon footprint) and the 'indirect' (i.e. the 'embodied' energies and carbon requirements) contributions to the total carbon impact from a product or service, within its lifecycle, will be accounted for. Comprehensive assessment *does not* imply the analysis of *all* impacts from tourism (for instance, acidification, ozone depletion and eutrophication). It concentrates on a single environmental impact category but strives to evaluate it as 'fully' as possible. The primary focus of this study is on tourism and climate change. The importance of other environmental and non-environmental impacts from tourism is acknowledged; however, they are beyond the scope of this thesis.

The '*life cycle*' concept is not new in tourism research. It has been broadly used in the context of evaluating the evolution of a tourist destination (see, for example, Rodriguez *et al.* 2008; Schuckert *et al.* 2007; Zhong *et al.* 2008). Despite the similarity in terms operated, this study does not tackle the issue of the tourist area or tourist destination's life cycle. Instead, it focuses on separate tourism products, such as tourist transport, accommodation and activities, or combination of these tourism products, such as holiday package tours, aiming to holistically assess the carbon impacts associated with each stage of their life cycle, i.e. from cradle (manufacturing) to grave (final disposal).

Throughout this study, reference is made to *'estimating'* GHG emissions, rather than 'measuring' or 'calculating' GHG emissions. This is because any emission factors developed by carbon inventories cannot be considered 100% accurate as they are usually based on averaged or region-specific values.

This thesis employs the term *'product'* to refer to both physical products, such as goods, and service products, such as services, throughout. Any substantial differences related to services are highlighted in the text.

1.4 CHAPTER OUTLINE

Chapter 1 serves as an introduction to the study which sets out its aim and objectives and justifies the necessity of research.

Chapter 2 examines the field of tourism environmental assessment. It reviews the key methodologies for impact appraisal in tourism, critically evaluating their strengths and weaknesses. The ability of the techniques to provide holistic estimates of tourism's contribution to the global carbon footprint is assessed. The chapter identifies the major issues raised, but not fully addressed, by existing carbon impact appraisal studies in tourism. The limited scale and scope of application of environmental assessments are discussed in detail. The exclusion of holiday package tours from holistic environmental appraisals is revealed and the necessity to conduct a more rigorous analysis of holiday packages within the short-haul travel settings, to better understand the relative carbon intensity of their specific elements along with the factors affecting the magnitude of the relative carbon intensity, is emphasized. The issue of the 'indirect' GHG emissions from tourism is introduced and its importance for comprehensive carbon footprint assessment of holiday travel is critically reviewed.

Chapter 3 provides an overview of the primary approaches to accounting and reporting on GHG emissions. The ability of these techniques to assess the magnitude of the 'indirect' carbon impacts is critically reviewed. The chapter discusses the applicability of these methods for carbon footprint assessment at a product or service level in the tourism context. The necessity to develop a reliable method which would be capable of producing the accurate and holistic estimates of the carbon impacts from tourism products is emphasized.

Chapter 4 introduces Life Cycle Assessment (LCA) as an established method for environmental appraisal of products and services. It examines the assessment framework and reviews the history of LCA application in tourism. The advantages of LCA over conventional techniques for appraisal of environmental impacts are critically reviewed and the shortcomings are outlined. Life Cycle Energy Analysis (LCEA) is introduced as a recognised method for holistic appraisal of products and services whose primary environmental impacts are known to stem from energy use. The chapter discusses the results of a pilot case study conducted to test the applicability of LCEA in the hotel sector and for holistic appraisal of a simplified aggregate tourism product, a weekend holiday tour. The necessity to extend the testing grounds of LCA (LCEA) to address such popular complex tourism products as holiday package tours is emphasised. The importance to conduct a comparative analysis of LCA (LCEA) against established methods for carbon footprint assessment in tourism is demonstrated.

Chapter 5 introduces a case study of a holiday package that aims to provide more empirical evidence on the application of LCA (LCEA) in tourism by conducting a holistic carbon footprint assessment of a standard short-haul holiday package in the British tourism market. The criteria for selection of a suitable research object are outlined. The goal and the scope of research are defined, the system boundary for LCA (LCEA) is set up and the functional unit for analysis is discussed. The chapter critically evaluates the basic data requirements for assessment and reviews the primary approaches for data collection. The necessity to carry out a survey on tourist activities to better understand their contribution to the total carbon footprint from a holiday package is emphasized. The approach to conducting a survey is introduced and the procedure for data analysis is discussed.

Chapter 6 conducts an inventory analysis of the holiday package selected as a research object for a case study. The results of the survey on tourist activities are presented and critically discussed. The individual 'tourist activities' profiles of survey respondents are established and analysed in detail. The consumption patterns of tourists at home and at the destination are thoroughly examined in relation to the associated carbon impacts.

Chapter 7 performs an in-depth assessment of the carbon impacts from the holiday package. The relative carbon significance of different holiday travel elements is critically evaluated. The estimates of the carbon footprint produced by LCA (LCEA) are compared against the figures suggested by alternative methods for carbon impact appraisal in tourism. The differences in estimates are revealed and the reasons for discrepancies are critically reviewed. The advantages and disadvantages of the reviewed assessment techniques are evaluated. A new, hybrid approach, capable of producing the most holistic and accurate values of carbon footprint from holiday travel, is proposed and its applicability is demonstrated. The contribution of the 'indirect' GHG emissions to the total carbon footprint from the holiday package is identified and its implications are discussed.

Chapter 8 deals with the sensitivity and scenario analyses. A sensitivity analysis is applied to demonstrate how the variance in operational parameters and/or structural variables of the holiday package affects its total carbon footprint. A scenario analysis aims to show how the choice of travel mode to/from the destination determines the magnitude of the GHG emissions from short-haul holidays. The relative carbon significance of specific elements of the holiday package under the different 'travel to the destination' scenarios is critically discussed.

Chapter 9 brings together the findings of this study and reviews them in relation to the research objectives. The implications of the research for the enhancement of the methodological base of tourism carbon impact appraisal are critically discussed. The contribution of the study to better understanding of the relative carbon intensity attributable to different elements of short-haul holidays is evaluated. The chapter concludes by consideration of the contribution to knowledge, study limitations and suggestions for further research.

1.4 SUMMARY

The chapter set out the rationale for this thesis. It has demonstrated the relevance of the research topic to contemporary impact assessment studies in tourism and, more generally, to the domain of environmental appraisal. The aim and objectives of the research are outlined and the general scope and limitations are stated. The chapter concludes by providing an overview of the thesis structure.

CHAPTER 2. ASSESSING THE CARBON FOOTPRINT OF TOURISM: A CRITICAL REVIEW

2.1. INTRODUCTION

This chapter reviews existing approaches for environmental appraisal of tourism impacts. The key techniques are identified and their strengths and weaknesses are critically evaluated. The potential of the reviewed approaches to produce accurate and holistic estimates of the carbon footprint from tourism products, services and activities is assessed. The issues raised but not fully addressed by existing carbon impact appraisals in tourism are established and the implications are critically discussed.

2.2. ASSESSING THE ENVIRONMENTAL IMPACTS FROM TOURISM

Many experts have emphasized the importance of accurate quantification and broader evaluation of tourism's environmental impacts (Cole and Sinclair 2002; Gössling *et al.* 2002; Gössling *et al.* 2005; Patterson and McDonald 2004) whose magnitudes have rarely been comprehensively assessed (UNWTO 2007). One reason is the underestimation of environmental impacts imposed by service industries in general and the tourism sector in particular (Schendler 2003). Services have lower material intensities than manufacturing industries (Raggi and Petti 2006). Hence, they are typically viewed as less environmentally damaging (Foran *et al.* 2005; Junnila and Nousiainen 2005), although this can be questioned in closer analysis (Graedel 1997; Rosenblum *et al.* 2000). Individual tourism businesses may cause minor environmental impacts; however, if all individual tourism operations are added together, the cumulative effect on the environment is significant (Kirk 1996).

Another reason for limited research on environmental assessment of tourism impacts is the lack of basic data required to holistically appraise the environmental performance of specific tourism products, services and activities. This is a consequence of the diversity and complexity of the tourism sector along with the corresponding difficulties of obtaining data at reasonable costs (Becken and Simmons 2008; Byrnes and Warnken 2006). This is also a result of poor understanding of the data quality requirements for environmental assessment among service companies (Junnila 2006b). This issue can be magnified by the hostility of tourism businesses to share data on, for example, energy consumption, as this information is often considered as profit and public image sensitive.

The fundamental reason is however that the research on sustainability assessment tools and their application in tourism is still in its infancy (Collins *et al.* 2007; Hunter and Shaw 2007; Sonak 2004). No commonly accepted method for assessing the environmental performance of services, including those related to tourism, exists (Wong 2004 cited Junnila 2006a), while the techniques in use have limitations. Accuracy in detection of environmental impacts, holistic evaluation of 'direct' and 'indirect' environmental effects and problems with system boundary setup for analysis are the critical issues (Wong 2004 cited Junnila 2006a). In addition, many environmental appraisal tools in services are directed at particular professional groups and can produce specialized results which are difficult to interpret by non-professionals (Collins and Flynn 2005). The absence of reliable assessment methods and easy-to-understand environmental impact indicators makes it difficult to measure the progress of tourism towards the goal of sustainability (Bicknell *et al.* 1998) and hampers the effectiveness of environmental decision-making (Becken and Simmons 2008).The need for environmental appraisal tools that are scientifically robust but, concurrently, accessible and have the capacity to communicate the key environmental concerns to a broad range of professionals and the wider community is recognized (Collins and Flynn 2005).

Importantly, the availability of reliable tools for assessing environmental impacts from services is crucial not only for academics and policy-makers but also for businesses. This is because environmental impact appraisal has implications for corporate management and sustainability reporting (Berners-Lee *et al.* 2011). Service companies are often highly visible to the public and may therefore experience a constant pressure from stakeholders to improve their environmental performance (Jayne 2000 cited Junnila and Nousiainen 2005). To develop any improvement measures, the actual environmental impacts need to be accurately assessed and quantified.

The literature review suggests that a limited number of environmental appraisal methodologies have been developed in tourism so far (Bicknell *et al.* 1998). As a result, researchers into environmental impacts of tourism tend to depend on subjective judgments, often with no reference to any assessment standards or criteria-supported measurements (Beccali *et al.* 2009). The lack of efficient environmental assessment techniques is particularly acute for measuring tourism's carbon impacts, where accurate and holistic quantification of greenhouse gas (GHG) emissions associated with specific tourism products, services and activities are necessary (Becken and Patterson 2006; Berners-Lee *et al.* 2011; Bode *et al.* 2003). This causes poor awareness and lack of understanding of tourism's contribution to the global carbon footprint (Gössling *et al.* 2006). Alarmingly, this problem is typical not only for the general public, but also for tourism experts (Becken 2004). This is partially because the tourism-related research alone does not possess appropriate methods for accurate and holistic assessment of tourism's environmental impacts. To rectify this, further development of existing assessment techniques and/or adaptation of new, holistic and consistent methodological approaches from other scientific disciplines are required (van den Bergh and Verbruggen 1999; Collins *et al.* 2009).

2.3. METHODS FOR ENVIRONMENTAL ASSESSMENT OF TOURISM IMPACTS

The scientific quality of existing environmental impact appraisals in tourism has room for substantial improvements (Lundie *et al.* 2007). The methods for determining tourism impacts are often inadequately specified and the magnitudes of environmental burdens they seek to establish are poorly quantified (Warnken and Buckley 1998). Previous research has predominantly aimed to either merely identify and list the diversity of tourism impacts, with no in-depth evaluation of their consequences (see, for example, Holden 2008; Hunter and Green 1995; Middleton and Hawkins 1998; Mieczkowski 1995; Mowforth and Munt 2008), to study tourist perceptions of environmental impacts from tourist activities (see, for example, Ap 1992; Becken 2004; Becken 2007; Dalton *et al.* 2008; Dickinson *et al.* 2009; Dolnicar *et al.* 2008;Gössling *et al.* 2006; Kelly *et al.* 2007a; Kelly *et al.* 2007b), or to examine the attitudes of tourism industries towards the complex 'tourism-environment' interactions (see, for example, Becken 2005; Bohdanowicz 2005; Bohdanowicz 2006; Bohdanowicz and Zientara 2008; Dalton *et al.* 2007; Gössling and Peeters 2007; Lawrence 2009). Attempts to comprehensively evaluate the environmental impacts from tourism are limited to a small number of environmental appraisal tools.

2.3.1 Ecological Footprint Analysis (EFA)

Ecological Footprint Analysis (EFA) has growing applications in tourism in the number of studies undertaken, diversity of use and scope of application (Table 2.1). Despite a number of strengths, EFA has been repeatedly criticized, predominantly for its limited analytical rigour, poor applicability to policy-making and often significant uncertainties in estimates (van den Bergh and Verbruggen 1999; Collins and Flynn 2005; Collins and Flynn 2008; Collins *et al.* 2007; Collins *et al.* 2009; Ferguson 1999; Holden and Hoyer 2005; Hunter and Shaw 2007; Schianetz *et al.* 2007). The most important shortcomings stem from the following:

Table 2.1. Tourism-related EFA studies by geographical scope and sector of application.

Source	Geographical scope of application	Sector of application
Bagliani *et al.* (2004)	Province of Venice (Italy)	Tourist destination
Cole and Sinclair (2002)	Himalayas (India)	
Gössling *et al.* (2002)	Seychelles	
Patterson (2005)	Province of Tuscany (Italy)	
Patterson *et al.* (2007)		
Patterson *et al.* (2008)	Province of Siena (Italy)	
Peeters and Schouten (2006)	Amsterdam (the Netherlands)	
Sonak (2004)	Goa (India)	
Zhang and Zhang (2004)	Huangshan City (China)	
Castellani and Sala (2008)	Alpi Lepontine Mountain community (Italy)	Tourist destination, accommodation
Johnson (2003)	Ontario (Canada)	
Purvis (2008)	Ontario and Quebec (Canada)	
Hunter and Shaw (2005)	Various (International)	Tourist destination, ecotourism
Nichols (2003)	Queensland (Australia)	
Collins and Flynn (2005)	Cardiff (UK)	Sport event
Collins and Flynn (2008)		
Collins *et al.* (2007)		
Collins *et al.* (2009)		
Chambers (2004)	Bulgaria	Holiday package
Peng and Guihua (2007)	Yunnan province (China)	
World Wild Fund-UK (2002)	Majorca (Spain) and Cyprus	
Hunter and Shaw (2007)	New Zealand, Costa Rica, Manaus (Brazil)	Holiday tour, tourist destination
Barrett and Scott (2003)	Merseyside (UK)	Passenger (including leisure) transport
Martin-Cejas and Sanchez (2010)	Lanzarote island (Spain)	Passenger transport for leisure purposes

- Implicit assignment of the magnitudes of environmental impact to whole impact categories. For example, built-up and arable land categories are given identical values of environmental impact, although motorways, which belong to built-up land, can have higher environmental impacts than arable land, at least in terms of the GHG emissions and heavy metals released;

- Limited ability to comprehensively account for some acute environmental impacts. For example, the use of pesticides or groundwater pollution translate into a relatively small contribution to the total ecological footprint of agriculture whereas their real long-term and feedback environmental effects can be significant, particularly the impact on human health and eco-toxicity;

- No account of a full range of greenhouse gases is taken; only CO_2 emissions are incorporated. Although CO_2 is the primary greenhouse gas resultant from human activities, the exclusion of other GHG emissions, such as methane, may lead to over

20% underestimation of the present anthropogenically induced greenhouse effect (see Gauci 2004 for a detailed discussion).

- Best applied at national and sub-national levels while the lower scales of assessment are less addressed, mainly due to the issues with uncertainty and data availability;

- Poor potential of EFA to be used as a ‘prospective’ environmental assessment tool. Appraisal of the envisaged, rather than established, environmental impacts by EFA is fraught with significant uncertainties due to the issues with data availability. This hampers comparison of new product or service alternatives and hinders scenario analysis.

Despite the critique, EFA is currently the most popular method for assessing the environmental performance of tourism (Hunter and Shaw 2007; Patterson *et al.* 2007) representing a valuable attempt to measure its environmental impacts as very few alternative sustainability assessment approaches exist (Bicknell *et al.* 1998). Importantly, EFA has the potential to address energy consumption with associated carbon impacts (Huijbregts *et al.* 2010), although the limitations of the technique in producing the reliable assessments of carbon footprint are recognized (Ferguson 1999).

2.3.2 Environmental Impact Assessment (EIA)

Environmental impact assessment (EIA) is acknowledged as an appropriate tool to appraise the environmental performance of many tourism-related activities (Schianetz *et al.* 2007). Nonetheless, it has gained significant criticism. EIA is often too narrow in the temporal and spatial scope of application to account for the diversity of environmental impacts from tourism (Hunter and Green 1995; Lenzen *et al.* 2003). Gössling *et al.* (2002) argue, for instance, that the potential of EIA to provide rigorous information on environmental implications of different travel patterns is limited. There is further evidence that the overall level of the appraisal and prediction of potential environmental impacts is inadequate in a substantial number of EIA studies (Hunter and Green 1995; Warnken and Buckley 1998). Importantly, it is a site-specific rather than a global sustainability assessment method (Gössling *et al.* 2002; Ness *et al.* 2007). This suggests the limited applicability of EIA for complex appraisal of such global environmental impact as climate change.

2.3.3 Input-Output Analysis (IOA)

Input-Output Analysis (IOA) is a popular macroeconomic approach to describe specific industrial and service systems (Bin and Dowlatabadi 2005; Lenzen and Dey 2000; Lenzen *et al.* 2003). In carbon footprint terms, it can provide an estimate of the total energy and carbon requirements of a product or service (Fay *et al.* 2000). Though originating in economic research, its generalised frameworks have also been utilised in tourism environmental appraisal. As a basic inventory methodology for environmental loads, IOA is involved in different methods for quantifying environmental impacts, such as EFA, EIA and Life Cycle Assessment (LCA), representing a 'hybrid' economic-environmental assessment tool (see, for example, Lundie *et al.* 2007). It has been applied in tourism for the appraisal of environmental impacts associated with the hotel sector (Rosenblum *et al.* 2000), national tourism industries (Forsyth *et al.* 2008; Patterson and McDonald 2004), visitor markets (Lundie *et al.* 2007), and large-scale tourism-related projects (Lenzen *et al.* 2003).

The advantages of IOA are the theoretical completeness, truly holistic assessments of both direct and 'indirect' environmental impacts, use of publicly available standard data sources and a transparent evaluation procedure (Fay *et al.* 2000; Hendrickson *et al.* 1998; Menzies *et al.* 2007). It however suffers from a limited scope of application - primarily at macro scales, such as national industrial sectors, economies, tourism industries and tourist markets (Collins *et al.* 2009). Although efforts have been made to narrow IOA down and apply it locally (see, for instance, Albino *et al.* 2002), the evidence of its localised application (for example, at the level of a specific tourism company or a separate tourism product) is limited. Furthermore, IOA makes idealistic assumptions of proportionality between monetary and physical flows and has potentially significant uncertainties in data procurement (Lenzen 1998; Menzies *et al.* 2007; Nässen *et al.* 2007). The IOA estimates are based on balanced national accounts and are not adjusted for the GHG emissions embodied in imported goods and services (Berners-Lee *et al.* 2011; Bin and Dowlatabadi 2005).

The most critical limitation of IOA is however that it captures only the 'upstream' environmental impacts, such as those associated with raw material extraction, product manufacturing and its transportation to a final consumer, but ignores the environmental impacts associated with product use and final disposal (Joshi 2000; Junnila 2006b; Lenzen and Dey 2000). IOA is thus based on the partial 'cradle-to-gate' assessment approach (Sinden 2009) which implies that the environmental impacts from a product are no longer appraised once it has left the retailer's gate. This is in contrast to the ‘cradle-to-grave’ life cycle assessments which holistically account for environmental impacts from *all* stages of the product’s life cycle (see, for example, Spielmann *et al.* 2008). The lifetime of specific tourism products and services can be significant (Table 2.2) and often involves regular, resource-intense maintenance and refurbishments; hence, IOA is not considered reliable for measuring the total environmental impacts from an individual product or service (Fay *et al.* 2000). More specifically, in the tourism context, De Camillis *et al.* (2010) argue that the quality of data in IOA is not adequate for analysis of specific tourism products, services and activities. This is because the high data aggregation, which is often referred to as an ‘aggregation error’ (Berners-Lee *et al.* 2011), is typical for the IOA method (Junnila 2006b). While this suits the needs of assessments focusing on whole sectors of tourism or the economy, it hampers accurate analysis at lower scales of service sector companies and specific tourism products (Junnila 2006b).

Table 2.2. Life time of different tourism-related products and services and/or its specific elements.

	Product/service/its element	Life frame (years)	Source:
Transport	Transport infrastructure (for example, roads, rail tracks, lighting, petrol stations)	60-70	von Rozycki *et al.* (2003); Saari *et al.* (2007); Schafer and Victor (1999)
	Personal transport vehicle (for example, passenger car)	12-15	McKinsey and Company (2007)
	Bicycle	20	Saari *et al.* (2007)
Accommodation	Hotel building / Building of a service sector company / Building with hotel functions / Building with leisure and hospitality functions	50-100	Junnila (2004); König *et al.* (2007); Kuo *et al.* (2005b); Scheuer *et al.* (2003)
	Toilet and shower facilities in a hotel rooms	20	Scheuer *et al.* (2003)
	Hotel and office furniture (and most other equipment in hotel rooms)	6-10	Hotel Assets Manager, Premier Inn Hotel Poole Centre, personal communication, (10 April 2009); Junnila (2004); Rutes *et al.* (2001 cited Bohdanowicz 2006)
	Textiles in hotel rooms (for example, carpets, draperies, curtains)	4-5	
	PCs, mobile phones and other office electronic equipment	2-4, with a tendency to decrease	Junnila (2004); Thollier and Jansen (2008)

Although the IOA method is being refined to address its limitations (see, for example, Joshi 2000), the studies based on the improved techniques are still small in number and not available in the field of tourism environmental appraisal. Moreover, the improved method has its own drawbacks arising from the risk of double-counting, subjectivity and resource-intensity (Menzies *et al.* 2007).

2.3.4 Eco-efficiency

The principle of eco-efficiency is closely linked to resource economics (Gössling *et al.* 2005). The environmental impacts are analysed in relation to the economic benefits created (Becken and Simmons 2008). Despite the new research avenues outlined by this technique in tourism impact assessment, its application in the tourism domain is limited. Gössling *et al.* (2005) employed the concept of eco-efficiency for carbon impact appraisal of a tourist destination. Patterson and McDonald (2004) conducted an analysis of the environmental impacts from a national tourism industry. No further evidence of utilisation of this method in tourism has been found. Importantly, applying the concept of eco-efficiency for carbon footprint assessment of tourism products, services and activities has flagged up a few points which call for more in-depth evaluation (see 2.4.2).

2.3.5 Material Input per Service unit (MIPS)

Material Input per Service Unit (MIPS) is another environmental assessment method whose application has recently been expanded to the impacts of tourism. Tourism transport and hotel businesses have been the primary objects for appraisal (Lahteenoja *et al.* 2006; Lahteenoja *et al.* 2008; Salo *et al.* 2008). While simple in application, MIPS has important drawbacks; inter alia, its level of detail is not sufficient yet for a broader analysis of some specific impacts, including climate change (Lettenmeier *et al.* 2008). In fact, existing studies emphasize a further need for research on the applicability of MIPS for carbon footprint appraisal of products or services (Sinivuori and Saari 2006).

2.3.6 Carrying Capacity (CC)

The concept of Carrying Capacity (CC) came to tourism research from ecosystems and conservation studies (Simon *et al.* 2004). Despite the straightforwardness of the operated definitions, the possibilities for application of CC in tourism are limited (Gössling *et al.* 2002). The major criticism relates to the quantification of the maximum magnitude of environmental impact that the ecosystems can sustain. Many experts argue that it is not feasible to measure it, simply because it is immeasurable (Buckley 1999; Simon *et al.* 2004). Indeed, the scientific knowledge about the nature and complexity of natural processes is limited; therefore it is difficult to accurately estimate how much impact is too much for each specific ecosystem at a tourist destination unless complex modelling and forecasting studies are involved. Even if the latter approach is applied, uncertainty is unavoidable (Refsgaard and Henriksen 2004). As a result, many CC studies in tourism are limited to qualitative assessment of environmental impacts (Castellani *et al.* 2007). No in-depth quantitative evaluation is usually involved. Importantly, the capability of CC to estimate the carbon impacts from tourism is limited (see, for example, Brown *et al.* 1997; Jurincic 2005; Simon *et al.* 2004).

2.3.7 Methods specifically designed for estimating the carbon impacts

There are two methodological approaches which have been employed to quantify the contribution of tourism products, services and activities to global carbon footprint. The GHG conversion factors developed by the UK's Department for Environment, Food and Rural Affairs (DEFRA) can be used for estimating the carbon impacts from fuel consumption in transport and from energy use in buildings, such as tourist accommodation facilities (DEFRA 2009; 2010a). Likewise, the method adopted by Gössling *et al.* (2005) utilizes the aggregate GHG emission factors from various sources to estimate the carbon footprint from leisure transport and hotels. DEFRA's method is based on UK national statistics; hence, it provides the most reliable results for the carbon intensities of tourism products, services and activities in the UK. In contrast, Gössling *et al.* (2005) operate the global average GHG emission coefficients from the mid and end-1990s. These can be applied universally, but do not reflect the very large variations between countries. In addition, these coefficients are now out-of-date as they have not moved along with technological advances. Gössling *et al.* (2005) estimate the carbon footprint from direct fuel and energy consumption; the additional 'indirect' GHG emissions embodied, for example, in transport and energy-producing capital goods and infrastructure are not addressed. The method by DEFRA has recently been substantially revised and the 2010 version of its GHG conversion factors is capable of estimating not only the direct carbon impacts, but also the 'indirect' carbon footprint associated with the extraction of raw materials, production, transportation and storage of fuels, i.e. the fuel chain-related 'indirect' GHG emissions (DEFRA 2010a). Importantly, the method by Gössling *et al.* (2005) does not account for non-CO_2 GHG emissions. In contrast, these are quantified by the recent version of the GHG conversion factors from DEFRA (DEFRA 2010a). A more detailed overview of the DEFRA approach is provided in 3.2.4.

A few other GHG emission inventories have been developed for carbon impact appraisal of tourism. Becken and Patterson (2006), for example, have derived the carbon intensity coefficients for specific tourism products, services and activities. The application of these figures is however limited as they are New Zealand-specific and based on the energy use data and GHG emission conversion factors from the early and mid-1990s.

2.3.8 Carbon calculators as tools for estimating the carbon impacts from leisure activities

The GHG emissions from tourism and leisure-related activities can be estimated with the help of online carbon calculators. While the number of these tools is significant (Gössling *et al.* 2007), a critical analysis (see Appendix 1 for details) has identified important limitations:

- Limited functional scope of application: many calculators focus on the carbon footprint assessment of individuals and/or households. The estimates of carbon impacts from specific tourism business operations are rare. Moreover, most calculators concentrate on the transportation element of holiday travel where the GHG emissions from flying are the primary target. Other fundamental elements, such as accommodation and activities, are usually omitted (Chenoweth 2009).

- Limited geographical scope of application: the estimates produced by some calculators cannot be projected onto other localities or be applied in an international context. Since tourism involves international travel, such tools require additional geographical adjustments.

- Failure to disclose the original assessment methodology: only a small number of calculators explain the methods utilised for estimating the GHG emissions from tourism products, services and activities (Chenoweth 2009). This causes issues with data verification.

More in-depth analysis shows that many of the tourism-related calculators employ the original GHG conversion factors from DEFRA as a basis for carbon impact estimates (Figure 2.1). This implies that these tools cannot be defined as *independent* techniques for estimating the carbon footprint from tourism products, services and activities. They should rather be referred to as *derivatives* of the DEFRA method. Importantly, the analysis has revealed that many calculators do not provide details of the background data their estimates are based upon. Moreover, they do not regularly update their GHG emission databases. All this raises questions about reliability and currency of carbon footprint estimates produced by carbon calculators.

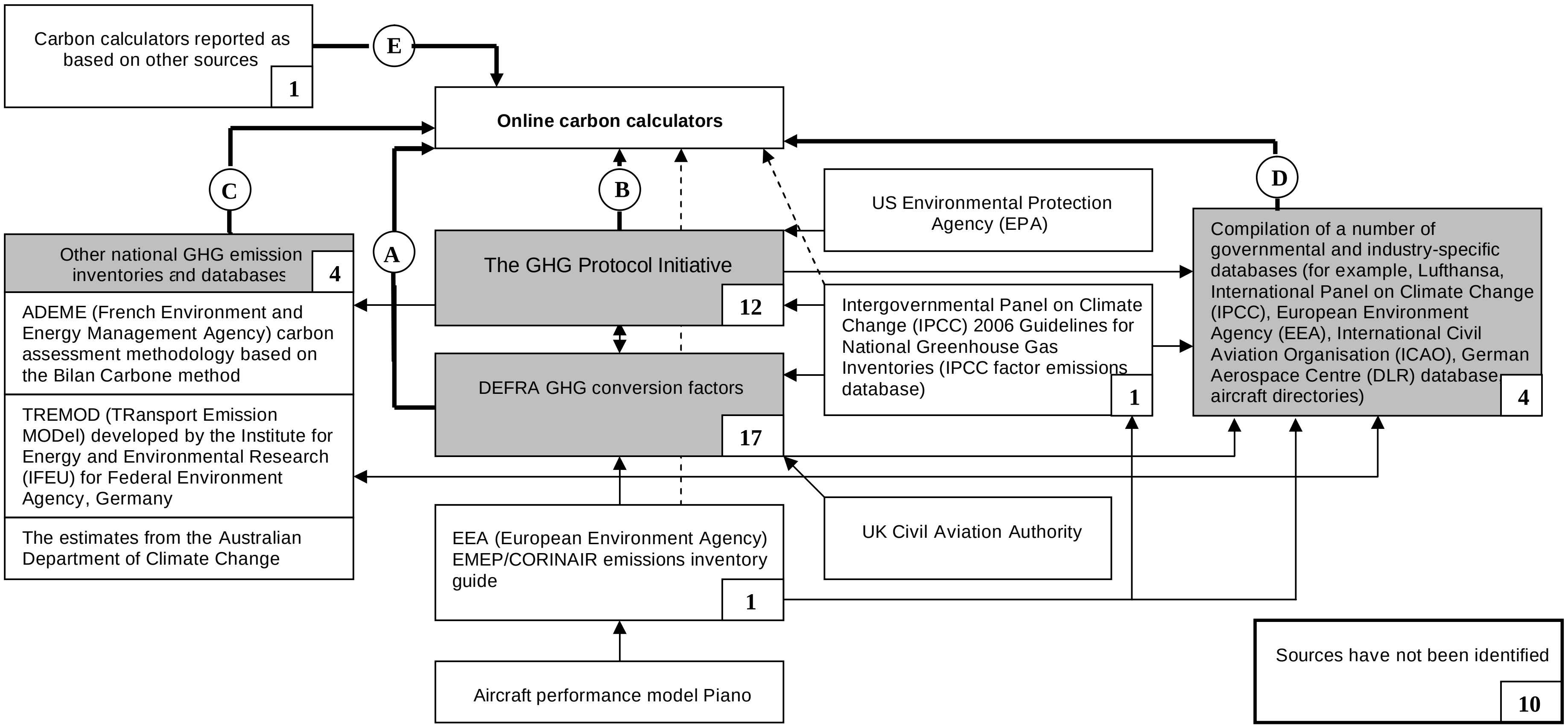

Figure 2.1. The primary data sources utilised by carbon calculators for estimating the GHG emissions from leisure-related activities.

Source: Author. Analysis is based on a review of 50 carbon calculators. Dark grey colour and thick lines represent the major sources. Numbers in boxes are the number of carbon calculators based on these sources. See Appendix 1 for details

- Failure to estimate the non-CO_2 GHG emissions: this issue is typical for irregularly updated calculators whose estimates are based on older DEFRA GHG conversion factors. This is because the pre-2009 DEFRA GHG inventories did not account for the whole range of GHGs. The implications of this shortcoming are discussed in section 2.3.1.

- Failure to account for the 'indirect' GHG emissions: while the calculators based on the most recent DEFRA GHG conversion factors are capable of estimating the 'indirect' GHG emissions related to the fuel chain, the 'indirect' carbon footprint attributable to the non-fuel-related capital goods and infrastructure is not currently estimated (Forsyth and Van Ho 2008; Statistical Analysis System - SAS 2009). The implications of exclusion of the 'indirect' carbon impacts are discussed in 2.4.5

2.3.9 Other methods

There are a few other methods for assessing the environmental impacts from tourism, such as Multi-Criteria Analysis, Adaptive Environmental Assessment, Limits of Acceptable Change, Concept of Yield, and Strategic Impact Assessment. However, they have limited application; therefore, the evaluation potential and scientific reliability of these tools are uncertain (Becken and Simmons 2008; Schianetz *et al.* 2007).

The critical analysis of the methods for assessment of environmental impacts from tourism suggests that existing techniques are small in number, imperfect and require refinement. Further sustainability appraisal tools need to be adapted to tourism to accurately assess its environmental impacts, especially in terms of carbon footprint, and to address the drawbacks of existing methodological approaches. New techniques, borrowed from other scientific disciplines, may effectively complement and be used in conjunction with existing methods to produce more reliable and comprehensive environmental assessments (Schianetz *et al.* 2007).

2.4. TOURISM AND ITS CARBON FOOTPRINT: SOME QUESTIONS OF IMPACT ASSESSMENT

The critical analysis of existing studies on carbon footprint assessment of holiday travel has identified a number of important issues which have been raised, but not consistently investigated, in the literature. A closer look at these issues is required to contribute to a better understanding of their significance and to identify the opportunities for resolution.

2.4.1 The relative carbon significance of different elements of short-haul holidays

Assessments have demonstrated that the environmental impacts from tourism are significant, especially in terms of the global GHG emissions, where they may account for up to 5% of the human-induced carbon footprint (Gössling 2002; UNWTO 2007). Among holiday travel elements[1], transport has been found to be the largest contributor (Byrnes and Warnken 2006; Dolnicar *et al.* 2010). It may produce between 50 and 97.5% of the total GHG emissions from tourism (see, for example, Gössling 2000; Gössling 2002; Hunter and Shaw 2007; Patterson *et al.* 2007; Peeters *et al.* 2006). The primary impact is attributed to air travel to/from the destination[2] whereas the share of other elements of holiday travel is believed to have a marginal value (Gössling 2002; Gössling *et al.* 2002).

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[1] Holiday travel consists of 1) transport, further subdivided into transport to/from the airport at country of origin, transport to/from the destination and local transport at the destination; 2) accommodation; and 3) activities, further subdivided into activities, entertainment and attractions (Becken and Simmons 2002). Food and fiber consumption (Gössling *et al.* 2002) and waste generation (Patterson *et al.* 2007; Peng and Guihua 2007) are sometimes considered as holiday travel elements.

[2] The estimates of the contribution of air travel to the global anthropogenic GHG emissions are uncertain. Today the figure 3.5% is widely used as a share of the man-made greenhouse effect associated with aviation (Gössling and Peeters 2007). However, some authors argue that this number is inaccurate. It does not, for example, consider the uncertainty imposed by radiative forcing (Gössling and Peeters 2007) which is deemed to be more damaging to the atmosphere than the GHG emissions alone. Some estimates therefore employ the radiative forcing (RF) coefficient which weighs the GHG emissions of air travel with a factor of 1.9-4.7 to account for a larger adverse carbon impact of aviation on atmospheric composition at higher altitudes (Grassl and Brockhagen 2007). The Intergovernmental Panel on Climate Change (IPCC) recommends, for example, to use the factor of 2.7 (Penner *et al.* 1999) and the UK Department for Environment, Food and Rural Affairs (DEFRA) suggests the factor of 1.9 (DEFRA 2009). These recommendations are however not widely followed (Carbon Clear 2010) as the science behind the RF effect is still uncertain (see, for example, Forster *et al.* 2006). If the RF coefficient is taken into account, the contribution of air travel to the global anthropogenic GHG emissions may be as high as 7% (Grassl and Brockhagen 2007) with the most pessimistic estimates quantifying the share of aviation at 9% (European Federation for Transport and Environment 2006).

While fair for long-haul or intercontinental travel, which inevitably results in very carbon-intense tourist trips regardless of any other factor (Chenoweth 2009), such an assertion is questionable when applied to short-haul holidays. Becken (2002) and Becken *et al.* (2003a) have shown, for example, that if tourists travel to/from the destination by overland modes of transportation or short-haul flights without changes, but stay in luxurious hotels and undertake energy-intense activities at the destination (for example, boat cruises, scenic flights), these non-transport elements of holiday travel may have a much more profound contribution to total GHG emissions. Similar conclusions were drawn by Peeters *et al.* (2006) with regard to a holiday trip based on short-haul rail travel. Likewise, for some short-distance trips, Chenoweth (2009) has demonstrated that the choice of accommodation and recreational activities at the destination has a much greater impact on the total GHG emissions from holidays than the choice of transport to/from the destination. Hunter (2002) also argues that for short-haul holidays to the mainstream tourist destinations, the destination-based elements of holiday travel can be the major contributors to its total carbon impacts. Thus, more scrupulous attention to carbon footprint assessment of short-haul holidays is required. This is particularly relevant given that short-distance holiday journeys remain the mainstay of tourist demand (Cooper *et al.* 1998 cited Lumsdon 2000).

The limited scope for affecting the energy consumption and associated GHG emissions from transportation to/from the holiday destination leaves other elements of holiday travel, such as accommodation, activities and travel at the destination, as important dimensions of the tourism industry calling for a more comprehensive environmental assessment with further development of effective mitigation measures (Warnken *et al.* 2004). The reduction potential for the energy use and GHG emissions that stem from transportation to/from the destination is theoretically substantial, but restricted in practice, as a result of numerous socio-economic and technological constraints (Bode *et al.* 2003). For example, while the carbon savings related to the use of hydrogen in vehicles are well recognized (Dougherty *et al.* 2009), the application of this technology in the transportation field faces a number of challenges related to its production, storage and distribution (Ball and Wietschel 2009). Likewise, the socio-economic issues of bio-fuel production hamper a broader utilization of bio-fuels in the transport sector (Rossi and Hinrichs 2011), although this may change in the future (Jones 2011).

In contrast, the magnitude of potential GHG emission mitigation at the destination is estimated as very high (see, for example, Gaglia *et al.* 2007), due to significant flexibility of local tourism service providers in selecting ‘greener’ energy use practices and suppliers (Bode *et al.* 2003; Bohdanowicz and Martinac 2003) and because of the yet considerable potential for improvements in their current energy and environmental performance (Dascalaki and Balaras 2004). The analysis of the service sector companies, including hotels, demonstrates, for example, that reductions of up to 20% of the overall energy use can be achieved at no or low cost (Junnila 2007).

2.4.2 Longer stay at the destination as a determinant factor for the relative carbon significance of holiday travel elements

The literature traditionally considers a longer stay at the destination as a factor increasing the eco-efficiency of holiday travel (Gössling *et al.* 2005; Peeters *et al.* 2006; Peeters and Schouten 2006), because the tourists' impacts at the destination are believed to be low. However, the results by Becken (2002), Becken *et al.* (2003a) and Chenoweth (2009) suggest that this is not necessarily the case. A combination of short-haul travel with no changes, long stay in an energy-inefficient hotel and regular energy-intense activities may result in a significant quantity of GHG emissions being produced at the destination reducing the share of the impacts from transportation. Recent studies show, for example, that tourists staying at the destination longer have a tendency to travel more often during their stay and cover larger distances than those visitors with shorter durations of stay (Becken 2008), thus increasing the carbon impacts associated with the destination-based elements of holiday travel. Moreover, there is evidence that even medium-haul air travel may have a lower contribution, i.e. lower than the conventionally accepted minimum share of 50%, to the total carbon impact of holidays if tourists have a longer stay in fashionable, but environmentally inefficient, hotels (World Wild Fund – UK 2002).

Since the current main tourism market is made up by short-haul and domestic destinations (UNWTO 2007) whose further growth is projected (Givoni and Rietveld 2008), especially in Europe (Peeters *et al.* 2007), there is a need for a more comprehensive analysis of the carbon impacts imposed by short-haul holidays. While the profound GHG emissions from long-haul travel are acknowledged, it is nevertheless important to better understand the carbon significance of short-haul holidays and accurately quantify the contribution of their specific elements, including travel, to the overall carbon footprint. The role of such factors as the duration of stay at the destination in altering the total amount of GHG emissions from holidays and the share of individual elements calls for more attention.

2.4.3 The limited scale of tourism carbon footprint assessments

The carbon impacts from individual holidays have rarely been assessed in academic tourism research (Peng and Guihua 2007). The primary focus has been on rather large, 'mega' or 'macro' scales - either tourist destinations (Castellani and Sala 2008; Chambers 2004; Gössling *et al.* 2002; Gössling *et al.* 2005; Hunter and Shaw 2007; Johnson 2003; Kelly and Williams 2007; Nichols 2003; Patterson 2005; Patterson *et al.* 2007; Peeters and Schouten 2006; Sonak 2004; UK Centre for Economic and Environmental Development - UK CEED 1994, 1998; Walz *et al.* 2008), national tourism industries (Becken and Patterson 2006; Forsyth *et al.* 2008; Patterson and McDonald 2004), different elements of holiday travel at a national level (Becken *et al.* 2001; Becken 2002; Becken and Simmons 2002; Becken *et al.* 2003a; Becken *et al.* 2003b) or tourism-related services and tourism supply chain sectors of economy (Lenzen 1999; Peeters *et al.* 2007; Rosenblum *et al.* 2000). This is partially because carbon impact appraisal of national tourism industries and their specific sectors is easier to perform due to better data availability and simplicity in the assumptions made (Bicknell *et al.* 1998). It is more difficult to obtain necessary data at regional and, in particular, local levels (Bagliani *et al.* 2008).

However, one of the principles of sustainable development 'think globally, act locally' suggests that much more attention should be paid to evaluation and mitigation of carbon impacts on smaller scales (Agenda 21 1992; Kirk 1996). While tourism imposes a number of large-scale environmental problems (for example, climate change) that can only be solved by global agreements, the experience shows that the progress must be made locally if effective improvements are to be achieved (Gössling 2009). According to Hunter (1995), a local focus is a must in sustainable tourism development, though the localised issues need to be addressed within a wider, national or sub-national, context. To partly address this need, increasingly more attention is being paid to assessment of tourism on smaller, 'micro' scales of specific holiday travel elements and separate tourism businesses, such as transport modes, accommodation categories, and activity types (Kelly and Williams 2007), also with regard to their impact on the environment (see, for example, Sara *et al.* 2004; Salo *et al.* 2008).

However, the elements of tourism have traditionally been analysed separately (Becken *et al.* 2003a) although they are often sold in combination, as a single product, a holiday package tour. There have been very few attempts to look at tourism products positioned at this 'intermediate' or 'meso' level, between specific holiday travel elements and national tourism industries.

Carbon impact appraisals of tourism on larger scales are fraught with significant uncertainties. There are a number of reasons for this:

Firstly, assessment and attribution of international aviation emissions is difficult, predominantly because the ‘rules’ for their allocation to individual economies are yet to be established (Forsyth *et al.* 2008). Secondly, the use of fuel in motor vehicles and the associated carbon footprint may also add uncertainty. In national inventories these are often included in the GHG emissions from the household sector although they can also be a significant component of tourism GHG emissions as a consequence of travel for leisure purposes. This results in underestimation of the carbon impacts from tourism and overestimation of the carbon footprint from the household sector (Forsyth *et al.* 2008). Thirdly, large-scale carbon impact appraisals are based on the data extracted from national inventories. These are usually well-standardized, maintained and updated in developed countries; hence, the analysis is relatively easy to perform. However, in many developing states national accounts are not robust and up-to-date (Menzies *et al.* 2007). This may result in significant uncertainties in estimates, particularly if the analysis is undertaken for

1) the national economy of a developing country;

2) an import-oriented national economy (especially small island states) with imports coming from developing countries (Foran *et al.* 2005).

Fourthly, the national statistics in developed countries provide quality data on domestic tourism but lack international standardisation. This hampers comparison and integration of data on the global scale (Peeters 2007). This problem is particularly acute in the tourist accommodation and activities sectors, where global information on the number of nights per accommodation category and on the volume and character of tourist activities is not available in sufficient detail. These issues are also typical for tourism transport as some global tourist flows and related carbon footprints are still not accurately quantified (Peeters 2007; Gössling *et al.* 2009); hence many crude assumptions have to be made (see, for example, Kelly and Williams 2007).

In contrast, carbon impact appraisal on the local level can be supported by more detailed information which is directly obtained ‘first hand’ from the provider. This contributes to more accurate and unbiased calculations, helps avoid simplifications and gaps in data procurement and thereby reduces the uncertainty of the final estimates.

This may have particularly important implications for carbon footprint assessment of tourism transport where a number of minor factors, such as vehicle type, fuel consumption, occupancy rate and itinerary affect the individual tourist's contribution to the global carbon impacts (Intergovernmental Panel on Climate Change - IPCC 1999 cited Gössling *et al.* 2007).

Finally, some authors argue that environmental achievements made at the local level of tourism products and services hierarchy, as a result of carbon impact assessments, can be easily scaled up and introduced to higher levels (Fortuny *et al.* 2008). This implies that tourism products, services and activities at the local levels are important testing grounds for future environmental actions applied at the global scale.

2.4.4 The holiday package as an object for carbon footprint assessment in tourism

The holiday package is deemed to be at the intermediate scale in the tourism product and service hierarchy. It represents an aggregation of different elements or travel choices – modes of transportation, types of accommodation and activities – offered to tourists as an integrated product. Hunter (2002) suggests that individual tourism products, such as all-inclusive holiday packages, are the most suitable units for environmental assessment in tourism, which should be conducted from the lifecycle perspective and on a 'per tourist' basis. This is because the individual providers of tourism products, services and activities, namely tour operators, travel agents, hotels and transport operators that directly contribute to the make-up of a holiday travel package, are usually the most accurate sources of consumption and pollution data required for environmental appraisal (Simmons *et al.* 2000). In contrast, environmental assessment at larger scales can be too crude due to the diversity of products and services involved in the evaluation process (Hunter 2002).

The environmental impacts from a holiday package have rarely been explored in detail and from a holistic perspective (Becken *et al.* 2003a), although globally holiday package tours are responsible for a significant share of leisure travel (Gössling 1999) and consequent carbon emissions (see, for example, Becken *et al.* 2003b). The literature reports three attempts to assess the environmental impact from an entire holiday package (Chambers 2004; Peng and Guihua 2007; World Wild Fund - UK 2002). Some studies (UK CEED 1994, 1998) have put all-inclusive holidays into the focus of environmental assessment but are incomplete because some elements have been omitted. Comprehensive assessments however help define which holiday choices result in the largest carbon footprint (Becken *et al.* 2003a). They can identify the 'hot-spots' within a package where the primary mitigation measures are necessary to reduce the overall impact. Only when the magnitude of the carbon impacts is established and the main causes discovered, is it possible to develop strategies for impact reduction (Becken and Patterson 2006). Last but not least, environmental assessments conducted at the scale of all-inclusive holiday packages are recognised as a driving force for the introduction of sound environmental management practices in the local tourism industries at popular tourist destinations (UK CEED 1998) and as a tool for raising environmental awareness among tourists (Tepelus 2005).

The necessity to conduct more carbon footprint assessments of holiday packages can be further justified by their significant share in the global and national leisure markets (Gössling 1999). In the UK, for example, 39% of all overseas holidays undertaken by Britons in 2008-2009 were all-inclusive package holidays (Office for National Statistics 2010). Although the share of holiday package tours has dropped by 15% since 1999 (Chambers 2004), they continue to play an important role in the British tourism market. Globally, this has resulted in some travel agents becoming specialized in holiday package tours which now make a significant share of their revenues (see First Choice 2010).

Importantly, about 65% of all British package holidays in 2008-2009 were short-haul as they were taken within the European Union (Office for National Statistics 2010). This further underlines the importance of conducting carbon footprint assessment of *short-haul* holiday packages in the British tourism market (see 2.4.1).

Last but not least, more accurate environmental assessments of holiday patterns attributed to British tourists are required because Britons are one of the most frequent travelers in the world (Hamilton and Tol 2007). Together with the Irish and the Germans they account for 25% of the international tourist market, taking on average 3 holidays per person per year (Hamilton and Tol 2007). Although these numbers may have recently decreased due to the financial recession, their share remains significant.

At the same time, there have been a few instances of increased demand for environmental assessments from tourism commercial operators. Peeters and Schouten (2006) report, for example, that the research on environmental assessment of tourism impacts in Amsterdam was requested by a tour operator willing to develop more sustainable tourism packages. High recognition of the value provided by environmental assessments for business success is typical for modern international service companies (Bohdanowicz and Zientara 2008) which often consider sustainability a strategic issue (Junnila 2004) for which they need to take ethical responsibility (Hoyer 2000; Kirk 1996) and seek to improve environmental performance in their daily business practices (Becken *et al.* 2003b; Berners-Lee *et al.* 2011; Bohdanowicz *et al.* 2004a). Demonstration of a sense of environmental awareness for them is often a means to achieve social status (Gössling *et al.* 2009; Karagiorgas *et al.* 2006) and competitive market advantages (Bohdanowicz *et al.* 2004b; Iwanowski and Rushmore 1994; Warnken *et al.* 2004); it is also a good way to protect the business reputation and prepare for tighter environmental regulations (Berners-Lee *et al.* 2011). The outcome of environmental assessments can be utilised in the company's annual sustainability reports; these, in turn, have been prescribed and encouraged in the principles of sustainable development (Chan 2005). They have become an important communication and marketing tool for many service-oriented companies (Bohdanowicz and Zientara 2008; Budeanu 2007), including leading tourist accommodation providers (see, for example, Scandic 2009). Last but not least, good environmental performance may diminish the companies' operational costs (for example, due to higher energy efficiencies). Monetary savings are usually the primary incentive for businesses to become more environment-conscious (Chan and Lam 2003).

Importantly, the level of interest in environmental issues expressed by tourism companies may depend on business size (European Union's Financial Instrument for the Environment 2001). Many large companies are increasingly required to display their environmental and social commitments and achievements; they have more resources available and need to maintain a good brand image. As a result, large tourism businesses are often more active in environmental issues than small tourism businesses (Becken 2003). Bohdanowicz (2005) has shown, for example, that chain-affiliated hotels in Europe have a higher emphasis on environmental attitudes than individually-owned and managed accommodation facilities. This is also because they employ more specialized personnel and provide a wide range of functions/services to which such environment-conservation measures as, for instance, energy saving can be applied (Becken 2003). All this implies that large tourism businesses, especially those with international activities, may be interested in the results of environmental assessment of their products and services.

To summarize, the literature demonstrates the necessity to conduct more carbon impact appraisals of holiday package tours, rather than national tourism industries, entire holiday destinations or separate travel elements. This will help better understand the magnitude of carbon impacts attributed to these popular tourism products and establish some representative values for holiday packages with specific parameters. This will also provide an insight into the individual contribution of tourists to the global carbon footprint. Furthermore, short-haul holidays have been identified as the most interesting objects for research due to the important role they play in the British and international tourism markets.

2.4.5 The 'indirect' carbon footprint from holiday travel

The critical analysis of the literature suggests that a major issue omitted in tourism carbon footprint assessment is that of 'indirect' carbon impacts (Gössling 2009; Hunter 2002). Existing estimates of the GHG emissions from tourism products, services and activities are incomplete as they appraise only the 'direct' carbon footprint while the 'indirect' carbon requirements are not addressed (Patterson and McDonald 2004). As Hunter (1995) states, traditionally, the scope and scale of concern in research on tourism environmental impacts have been limited to the 'direct', immediate and tangible effects.

The direct carbon impacts are easier to quantify as the 'indirect' carbon contribution can be manifold, complex, hidden and therefore difficult to assess (Lenzen and Dey 2000). An important question is to what extent the overall carbon impact of tourism products, services and activities changes when the 'indirect' carbon contribution is added to the picture (Lenzen 1999). Another point of interest is how the 'indirect' carbon footprint alters the relative share of different travel elements in the total GHG emissions from holiday travel. Overall, Lenzen and Dey (2000) argue that carbon impact appraisals need to adopt a holistic approach in order to estimate the *full* magnitude of environmental impacts. This should assist decision-making in developing more effective measures for carbon footprint reduction (Lenzen and Dey 2000)

The 'indirect' carbon footprint arises from the non-use phases of a product or service life cycle; it is also embodied in the capital goods and infrastructure necessary to extract, transport and refine the raw materials, manufacture a specific product or service, deliver it to a final user and dispose of it (see Frischknecht *et al.* 2007a for definition). The 'indirect' carbon footprint also stems from renovation, refurbishments and maintenance (Figure 2.2). Together with the carbon impacts from the use phase, these 'indirect' GHG emissions are referred to as the 'life cycle' carbon requirements which represent the most holistic measurement of the product or service-specific GHG emissions (Frischknecht *et al.* 2007a).

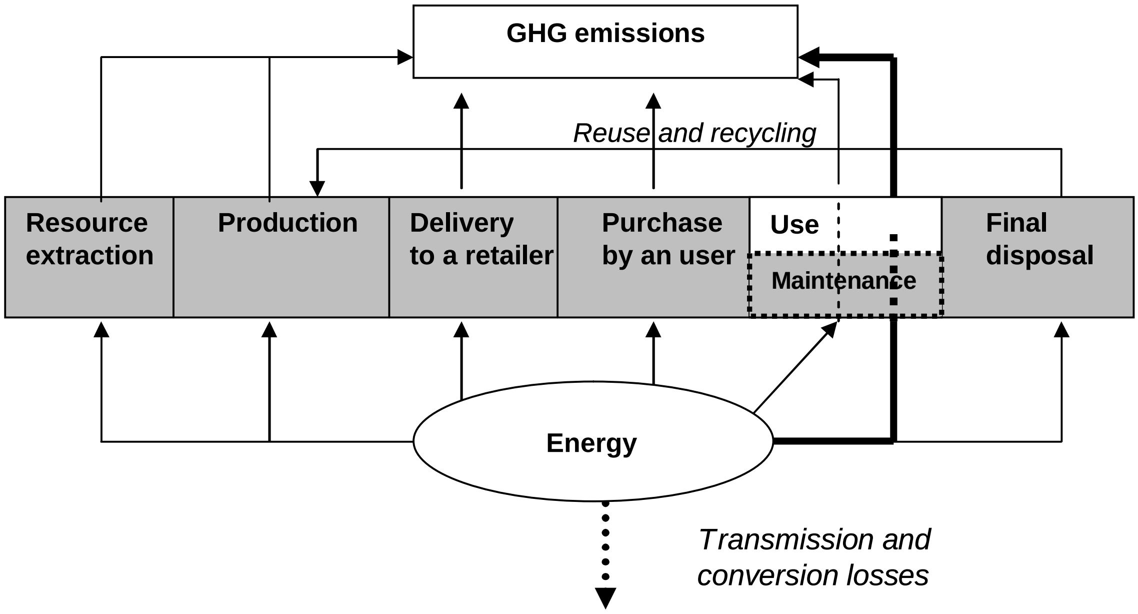

Figure 2.2. 'Direct' and 'indirect' carbon impacts arising during a product or service life cycle.

Source: adapted from Bin and Dowlatabadi (2005). White colour and thick black lines indicate the stages of the product/service's life cycle with the 'direct' energy consumption and associated carbon emissions. Grey colour and thin black lines show 'indirect' energy use and consequent GHG emissions.

The 'indirect' carbon footprint is less obvious and more difficult to measure (Fay *et al.* 2000) as it is often outside the control of the product or service provider and may even occur in foreign countries. For example, in a hotel, the direct or 'on-site' carbon footprint is associated with the GHG emissions from energy consumption by the hotel guests (Lundie *et al.* 2007); the 'indirect' or 'off-site' carbon impacts arise from the power plant that supplies electricity to the hotel, the factory producing steel for manufacturing this power plant's equipment, the mining operations providing the iron ore for the steel factory, etc. (Lenzen *et al.* 2003; Lundie *et al.* 2007).

The situation is further complicated when the 'indirect' GHG emissions from complex tourism products or services, such as holiday package tours, are appraised. The holiday package consists of a number of elements, i.e. transport, accommodation and activities, and each of these elements has 'indirect' carbon impacts embodied in the non-use stages of their life cycle, also related to the capital goods and infrastructure. In turn, some elements of the holiday package may consist of a number of structural sub-components which further magnifies the scope of the 'indirect' carbon footprint. In the case of holiday transport, for example, the direct GHG emissions stem from vehicle operation, i.e. fuel combustion in the vehicle's engine. The associated 'indirect' carbon impacts arise from the non-operational phases of the fuel life cycle, i.e. fuel production, storage, delivery and distribution (Koroneos *et al.* 2005). Holistic analysis of this carbon footprint represents the so-called 'well-to-wheels' environmental assessment of the fuel chain (Chapman 2007; Holden and Hoyer 2005). These 'indirect' GHG emissions are, for example, currently estimated by DEFRA (see 2.3.7). However, transport as an element of holiday travel also implies presence of a vehicle and the road infrastructure. These structural sub-components of transport have 'indirect' GHG emissions embodied in vehicle manufacture, maintenance and disposal (Bin and Dowlatabadi 2005; Spielmann and Scholz 2005) and the road infrastructure construction, maintenance and final disposal life stages (Frischknecht *et al.* 2007a; Lenzen 1999). Furthermore, vehicles (especially public transport) and the road infrastructure are characterised by extensive use and significant life frames (Table 2.2). This often results in frequent refurbishments and renovations which also have significant amounts of embodied energy and carbon footprint. All this implies that the life cycle GHG emissions from complex tourism products, such as a holiday package tour, have a number of dimensions (Figure 2.3). These are explained in detail on the basis of the 'transportation by coach' example.

The carbon impacts from transport by coach, as an element of a composite tourism product, i.e. a holiday package tour, are traditionally assessed from the single dimension (1D) perspective. This dimension is represented by the GHG emissions from vehicle operation, i.e. fuel combustion.

The second, 'vertical' dimension (2D) comes onto stage when the 'indirect' carbon footprints from the non-operational phases of the coach life cycle are considered, i.e. vehicle manufacture, transportation to consumer, maintenance and final disposal.

The third, horizontal dimension (3D) occurs when other indispensable components of the 'transportation by coach' element of holiday travel are taken into account, such as fuel and road infrastructure. Each of these components is characterised by the 2D 'vertical' structure of GHG emissions attributable to different stages of their life cycle. Importantly, while the number of indispensible components is small for the 'transportation by coach' element of holiday travel, this may not be the case for other elements of composite tourism products.

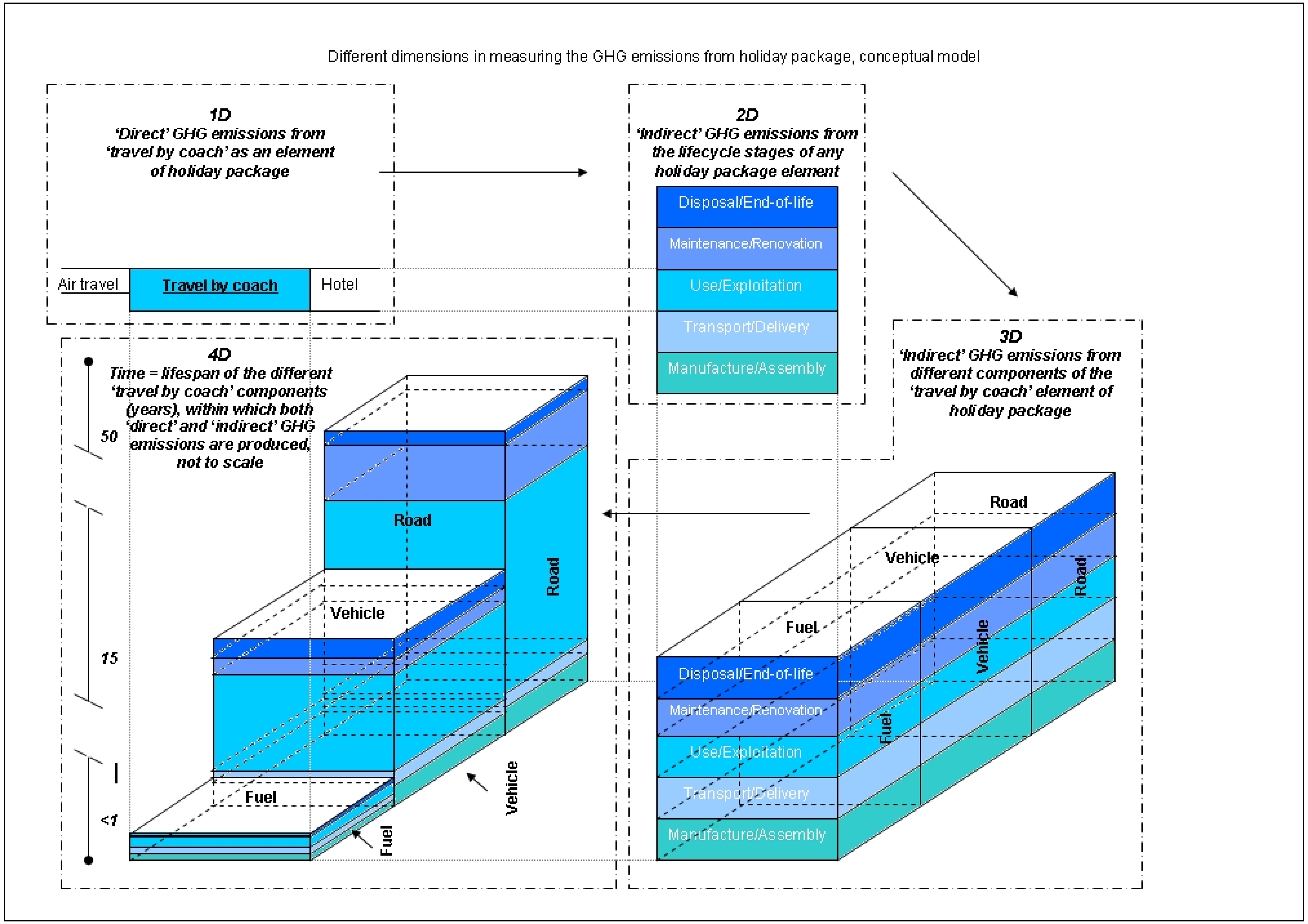

Figure 2.3. A conceptual multi-dimensional model of the life cycle GHG emissions from holiday travel; example of 'transport by coach'. *Source: Author*

Tourist accommodation is a good example. The third dimension of the life cycle GHG emissions from a hotel can be large as it will comprise of the carbon footprint embodied in the hotel building, electric and electronic appliances, kitchen equipment and room furniture; it will also relate to the hotel transport network and infrastructure (roads, car fleet, parking lots), food and beverages consumed by hotel guests, etc. (Kelly and Williams 2007). Again, all these components have the 2D carbon footprint embodied in the non-use phases of their life cycle.

Last but not least, the components of the 'transportation by coach' element of holiday travel are characterised by different durations of their life frame. The longer the life cycle of a specific component is, the greater its opportunity to undergo refurbishments and renovations which also contribute to the total carbon impact. For instance, the coach vehicle may have the life frame of about 15 years, within which it may go trough a number of essential services. The road infrastructure is even more likely to be regularly (and often substantially) renovated within its life frame of over 50 years. It is argued that the time may therefore represent the fourth dimension (4D) of the GHG emissions from composite tourism products.

It is further argued that all dimensions of the 'indirect' carbon impacts need to be accounted for, subject to data availability, should the accurate and comprehensive carbon footprint appraisals of holiday travel be conducted.

2.4.6 Assessing the 'indirect' carbon footprint from tourism

The 'indirect' impacts are usually not addressed in tourism's environmental appraisals. They are not required, for instance, for conventional EIA because of the perceived methodological difficulties of estimating this hidden contribution, combined with the assumption that they are insignificant (Frischknecht *et al.* 2007a; Lenzen *et al.* 2003). There is, however, a strong argument that 'indirect' impacts should not be excluded from environmental assessments; on the contrary, they need to be included, either as direct measurements and subsequent calculations or at least as estimates and educated guesses (Frischknecht *et al.* 2007a). From the global carbon footprint perspective, quantification of both direct and 'indirect' energy consumption and GHG emissions is critical to the design of more effective energy and GHG emission reduction policies (Bin and Dowlatabadi 2005).

There is further evidence that the 'indirect' carbon impacts from tourism can be high due to the diversity of products and services consumed by tourism activities (Becken *et* *al.* 2003a). Table 2.3 provides an overview of the estimates of the 'indirect' GHG emissions attributed to different tourism elements. Importantly, the majority of these estimates have been retrieved from studies conducted outside tourism. They show that the 'indirect' carbon footprint can be as high as 20% of the total for the accommodation sector and up to 65% of the total for tourism transport. The 'indirect' share in the tourism transport category may become even more dominant in the future following the introduction of more efficient engines and new carbon emission reduction technologies for vehicle operation (Spielmann and Scholz 2005).

Table 2.3. Estimates of the 'indirect' carbon impacts for different elements of tourism and leisure.

Source	How the 'indirect' environmental impacts are estimated	Tourism element
Høyer (2000)	Environmental impacts of accommodation, restaurants and related tourist services are predominantly attributed to the construction of the accommodation facilities and to a lesser extent related to their operation	Accommodation and hospitality
König *et al.* (2007)	The amount of energy necessary to construct a hotel building equates to 20% of the total energy consumption within its operational lifecycle of 80 years	
Barrett and Scott (2003)	'Indirect' GHG emissions associated with public transport manufacture and maintenance in the UK may account for about 30% of its total environmental impacts	Transportation and transport-related services
Cool Climate Network (2010)	'Indirect' well-to-pump' GHG emissions of jet fuels contribute 20% to the total carbon footprint of air travel	
Ericsson *et al.* (1996)	'Indirect' share of CO_2 emissions for road transport in Sweden is equal to 11% of the total if the environmental effects of fuel production are excluded and to 26% if these are included	
Forsyth and Van Ho (2008)	'Indirect' carbon emissions of the Australian international aviation equal 25-30% of the 'direct'	
Frischknecht *et al.* (2007a)	Within road-based passenger transport, manufacturing of vehicles and transportation infrastructure contribute 15-19% of the total GHG emissions	
Lenzen (1999)	'Indirect' energy requirements and GHG emissions constitute 25-65% of the total for different modes of passenger transport in Australia	
Lenzen *et al.* (2003)	'Indirect' energy consumption and GHG emissions associated with airport construction in Sydney (Australia) are an order of magnitude higher than its 'direct' carbon footprint	
Potter (2003 cited Chapman 2007)	'Indirect' CO_2 emissions of an average car constitute 24% of the total and arise from emissions and losses in the fuel supply system (15%) and from manufacturing of the vehicle (9%)	
Spielmann and Scholz (2005)	'Indirect' environmental impacts of vehicle infrastructure processes are important in the overall environmental performance of conventional transport services	
Spielmann *et al.* (2008)	Transport in Europe is characterised by the following magnitudes of the 'indirect' GHG emissions (per passenger kilometer, of total): personal car = 35%; coach = 20%; aircraft = 40%; bus = 20%; train = 60%	

Importantly, a high share of the 'indirect' carbon emissions from tourism transport may have significant implications for existing tourism carbon calculators and carbon offsetting schemes. This is because they do not allow for the 'indirect' GHG emissions, thus underestimating the total carbon footprint from travel (section 2.3.8). It is argued that, to be methodologically comprehensive and to assess the *overall* magnitude of the carbon intensity of tourism transport, carbon calculators and carbon offsetting programmes should account for its 'indirect' GHG emissions. These can also be included into a sensitivity analysis of the calculation results.

As for larger scale estimates, there are significant contradictions in evaluating the share of the 'indirect' carbon impacts from tourism. The United Nations World Tourism Organization-United Nations Environment Programme-World Meteorological Organization - UNWTO-UNEP-WMO (2008 cited Gössling 2009) argue the 'indirect' emissions of tourism to be in the order of 10-20%. Gössling (2009) therefore suggests that these should be included in calculations of the total tourism carbon footprint by multiplying the established, direct impacts by a factor of 1.15. Importantly, these estimates are based on scientific speculations, rather than on empirical measurements. A number of country and region-specific studies present much higher figures of the 'indirect' carbon impacts from tourism (Table 2.4).

Table 2.4. 'Large-scale' estimates of the 'indirect' energy use and carbon footprint from tourism.

Source	**Contribution of the 'indirect' requirements (%) in:**		**Area and scope of estimate**
	Energy use	*GHG emissions*	
Becken and Patterson (2006)		46	New Zealand domestic tourism
Bagliani *et al.* (2008)	47.8		Province of Siena (Italy)
Becken and Simmons (2002)	50		New Zealand domestic tourism
Forsyth *et al.* (2008)		52	Australian tourism industry

Some experts argue that even environmentally benign types of tourism (for example, sport activities or walking) may result in significant energy use and GHG emissions if the 'indirect' carbon requirements are taken into account (Becken and Simmons 2002). The studies by Lenzen (1999) and Chenoweth (2009) have demonstrated, for example, that even a bicycle may have substantial carbon impacts if the 'indirect' carbon requirements, such as those related to additional food intake by the cyclist, bicycle manufacture, maintenance and disposal, and road infrastructure for bicycle lanes, are considered.

The ‘indirect’ carbon impacts can be particularly significant for small and/or remote destinations (for example, small island states, such as Maldives, Seychelles, and Fiji) where most of the commodities consumed by tourism activities are produced and transported from ‘hinterlands’ (see, for instance, Gössling *et al.* 2002). World Wild Fund - UK (2002) has demonstrated that 73% of foodstuffs consumed by tourists in Majorca (Spain) are internationally sourced, 17% arriving from outside Europe. Frischknecht *et al.* (2007a) argue that the production of foodstuffs in general and organic produce in particular may have up to 15% ‘indirect’ GHG emissions. Additional significant carbon impacts are imposed by transportation between production and consumption. Uitdenbogerd *et al.* (1998 cited Jungbluth *et al.* 2000) suggest that the energy required for food preparation constitutes only 25% of the total energy use arising from foodstuffs, while over 60% is attributed to food production and delivery. Similar conclusions are drawn by Garnett (2011). Jungbluth *et al.* (2000) further show that knowing the geography of origin and the method of delivery are crucial in holistic, direct and ‘indirect’ GHG emissions inclusive, carbon footprint assessment of foodstuffs.

The ‘indirect’ carbon contribution is usually ignored in national carbon inventories (see, for example, Sim *et al.* 2007). Currently, the lack of knowledge on the total direct and ‘indirect’ magnitude of carbon impacts, especially in small and/or remote destinations, is the most important barrier to implementing appropriate carbon footprint mitigation measures in tourism (Becken 2005). All this calls for more accurate estimates and inclusion of the ‘indirect’ impacts into carbon footprint assessment of tourism products, services and activities (Becken and Simmons 2002). This enables a truly holistic appreciation of tourism’s carbon requirements (Hunter 2002) and more comprehensive evaluation of options for reducing energy consumption and GHG emissions (Lenzen 1999).

2.4.7 Supply chain as a contributor to the ‘indirect’ carbon footprint from holiday travel

The ‘indirect’ GHG emissions also stem from the supply chain industries (Frischknecht *et al.* 2007a), i.e. businesses providing auxiliary services to tourism operations. These ‘indirect’ carbon impacts can be significant as they have a high cumulative effect (Becken and Patterson 2006). Berners-Lee *et al.* (2011) argue, for example, that the majority of the carbon impacts from a service company are likely to lie in the supply chain.

Tourism is a composite and diverse sector (Becken *et al.* 2001); it is an aggregation of the tourism elements of other industries (Forsyth *et al.* 2008) that can be represented dendritically (Figure 2.4). Some authors even claim that tourism cannot be properly described as an industry because it does not produce a single, distinct product (Hunter 2002). In broader terms, tourism includes not only transport, accommodation, and activities but also a large variety of other products and services purchased by tourists in connection with their holiday travel or designed to support conventional tourism products and services (Becken *et al.* 2001; Ronning and Brekke 2009; Walz *et al.* 2008). These include, but are not limited to, food, beverages, laundry, buildings, vehicles, energy and transport infrastructure, financial and business services (Kelly and Williams 2007). The technologies delivering all these tourism amenities are energy- and GHG-intense (Tabatchnaia-Tamirisa *et al.* 1997 cited Kelly and Williams 2007); hence, the consequent carbon impacts may be minor for each tourism supply chain industry, but significant if added together (Patterson and McDonald 2004). Moreover, the relationships between tourism and its supply chain industries are non-linear: if the tourism industry, for example, was to expand by 10%, the associated GHG emissions could increase by more than 10%. Changes in the size of the tourism industry will induce changes in its supply chain and these may be higher than forecasted due to the complexity of inter-linkages and the diversity of services involved (Forsyth *et al.* 2008). Although some experts argue that it is more pragmatic to consider for assessment of environmental impacts only those industries which are 'tourism-characteristic'[3] (Becken and Patterson 2006), it would be better to understand the *total* energy use and associated carbon footprint (Becken and Simmons 2002).

Tourism suppliers play a significant role in the carbon impacts from different tourism products and services. Rosenblum *et al.* (2000) have found that only 7% of the GHG emissions from the hotel sector in USA are generated by the hotels alone. The remaining 93% are produced by the supply chain industries. These results are in broad agreement with the conclusions of Lenzen (1998) who calculated the 'indirect' energy use and GHG emissions as high as 90% for service industries (including recreation) in Australia. Becken *et al.* (2001) have found that 67% of the total energy use and associated GHG emissions in the New Zealand's hotel sector stem from the services and facilities which are not directly related to accommodation (for example, restaurant, casino, swimming pool). Collins *et al.* (2007, 2009) have estimated the carbon footprint from the supply side industries as equal to 45-64% of the total GHG emissions from a large-scale sport event. Although Becken and Patterson (2006) have excluded

[3] 'Tourism-characteristic' industries include accommodation and catering, transport, equipment hiring and cultural and recreational services (Becken and Patterson 2006).

restaurants from the environmental analysis of the hotel industry in New Zealand assuming their contribution to be negligible, Salo *et al.* (2008) have demonstrated that this is not necessarily the case. The inclusion of restaurants into environmental appraisal of hotels may increase the overall resource consumption and GHG emissions by about 20-30%. Junnila (2006b) has argued that exclusion of the supply chain and restaurant/catering services may reduce the estimates of the total environmental impacts from a service sector company by 25-40%. Similar conclusions are drawn by Berners-Lee *et al.* (2011) in relation to the GHG emissions from a large tourism business firm in the UK. Castellani and Sala (2008) have found that the contribution of laundry and restaurant services to the total environmental impact from the accommodation sector at a small destination may equate to at least 45% for 4-star hotels and as high as 90% for 1- and 2-star accommodation facilities.

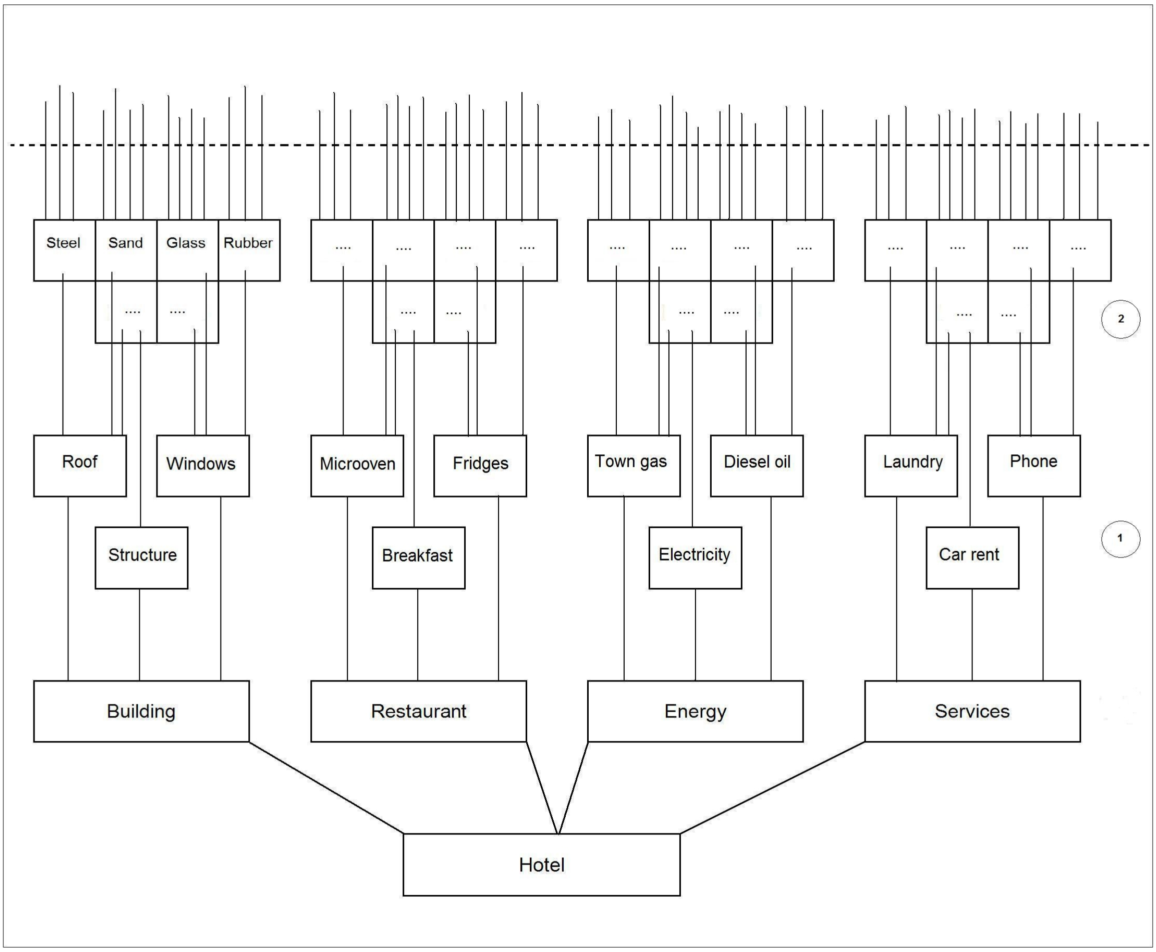

Figure 2.4. Schematic diagram of a dendritic structure of tourism suppliers.

Source: Author. Rectangular boxes indicate suppliers. The numbers in circles on the right side represent the level of suppliers. The list of the hotel suppliers is not comprehensive and can be extended to include a large number of other products and services.

In general, most tourism businesses have limited awareness of the environmental impacts from their supply chain industries and rarely connect their own environmental performance with these 'indirect' impacts (Bohdanowicz 2006; Chan and Lam 2002). At the same time the purchasing power of a single tourism business can be substantial (Bohdanowicz 2006). This suggests that tourism businesses have the power to demand more environmental responsibility from their supply side. To identify and measure environmental 'hotspots', the supply chain should preferably be included into tourism sustainability assessments (Lundie *et al.* 2007; Rosenblum *et al.* 2000), subject to data availability. Estimating the GHG emissions from the supply side is recommended, but not yet required, by existing tools for corporate carbon footprint accounting and reporting (DEFRA 2010a; The Greenhouse Gas Protocol Initiative – GHG Protocol 2011). See Chapter 3 for discussion.

The fundamental issue related to estimating the environmental impacts associated with the supply chain industries of specific tourism products and services is the system boundary setup for analysis (Foran *et al.* 2005). Supply chains can be of infinite order; moreover, some suppliers can be difficult to identify (Wong 2004 cited Junnila 2006a). Lenzen *et al.* (2003) suggest that at least 6 consequent supply chain levels need to be considered in order to account for 90% of the entire system's direct and 'indirect' environmental impacts. This, however, can be cumbersome and even impossible (Lenzen *et al.* 2003). A solution can be provided by the large-scale, hybrid economic-environmental input-output analysis (IOA) based on the data from national inventories (see, for example, Hendrickson *et al.* 1998). This takes a top-down approach and treats the whole national economy as the boundary of analysis (Joshi 2000). This method cannot be however used for environmental appraisal at lower levels of specific tourism products and services (see 2.3.3), where reasonable simplifications and the establishment of feasible system boundaries are necessary. Existing approaches to environmental assessment do not extend above the first level (first-order) of suppliers, such as on-site emissions of a hotel, and emissions from a power plant that supplies electricity to this hotel (Lundie *et al.* 2007). The important task of environmental appraisal tools in tourism is therefore to demonstrate the relative significance of the different orders of suppliers in the total environmental footprint of tourism products, services and activities in order to justify sensible system boundary setup for future environmental assessments.

2.4.8 Holistic assessment of carbon impacts from holiday travel

The adoption of holistic impact assessment in tourism has been slow although it may provide a more complex and broader perspective on its impacts (Patterson and McDonald 2004). Despite the apparent necessity to make a comprehensive analysis of tourism products, services and activities with inclusion of both direct and ‘indirect’ carbon footprint, very few holistic sustainability assessments of holiday travel have been attempted so far. Moreover, a very limited number of existing environmental appraisals have conducted an analysis of both direct and ‘indirect’ effects from the life cycle perspective and at the level of specific tourism products and services (Chambers 2004; Patterson and McDonald 2004), although the necessity to apply the life cycle approach for carbon impact evaluation in tourism has been repeatedly emphasized in the academic literature (see, for example, Gössling *et al.* 2005; Hunter and Shaw 2007). Thus, there is a clear need to develop a reliable, simple-to-understand, but comprehensive environmental assessment methodology which would be capable of accounting for both direct and ‘indirect’ GHG emissions. Furthermore, there is also a clear need to test this methodology on tourism products.

2.5. SUMMARY

A critical review of the key methods for environmental assessment of tourism impacts has demonstrated that this field is under-developed, especially in terms of carbon footprint appraisal, as only a small portion of existing techniques are capable of estimating the GHG emissions. In turn, these tools have a number of limitations which hinder accuracy, reliability and comprehensiveness of estimates. This implies that the research on tourism carbon impact appraisal would benefit from methodological enhancement of existing techniques and/or adaptation of new tools which have an established reputation for reliable carbon footprint assessment outside of tourism. The employment of new methods can provide new outlooks on the carbon impact appraisal of tourism products, services and activities. A comparative analysis of different methodological alternatives for estimating the GHG emissions from tourism can identify or facilitate development of the most accurate and holistic assessment tool.

More accurate carbon impact appraisals are required for short-haul holidays because controversy exists in the literature when estimating the relative carbon significance of their specific structural elements. More comparative research on the GHG emissions from the destination-based elements versus the transit elements of holiday travel is necessary to design more effective mitigation measures for short-haul trips with specific parameters.

To enhance the quality of carbon impact appraisal in tourism, the application scale of existing assessments needs to be extended to cover such popular tourism products as holiday package tours. These have never been holistically assessed, albeit their significance in the international and regional tourism markets is recognized. Establishing representative values of GHG emissions for holiday packages with specific parameters is required to better understand the contribution they make to the global carbon footprint. Development of a comprehensive framework for assessment of composite tourism products is necessary to identify the basic data needs and outline effective procedures for their collection.

Extending the scope of carbon impact appraisals in tourism is also required. The 'indirect', non-use phase-associated GHG emissions, also arising from the capital goods and infrastructure, are an important issue to address. The significance of the 'indirect' carbon footprint has been recognized outside tourism while reliable estimates of the 'indirect' GHG emissions have never been established for popular tourism products, services and activities. Inclusion of the 'indirect' carbon footprint into tourism carbon impact appraisal enhances the comprehensiveness of assessments and helps produce more accurate and reliable estimates.

The next chapter discusses the issue of appraising the 'indirect' GHG emissions in more detail. The major dimensions in estimating the 'indirect' carbon impacts are outlined and their implications for tourism are evaluated. The key approaches to address the 'indirect' carbon footprint are critically reviewed.

CHAPTER 3. ASSESSING THE ‘INDIRECT’ CARBON FOOTPRINT

3.1. INTRODUCTION

The ‘indirect’ carbon impacts are difficult to identify and appraise (Fay et al. 2000), especially for service industries where the complexity and diversity of the sector further complicate the task (Junnila 2006a). The ‘indirect’ GHG emissions are often referred to as the ‘grey’ or ‘embodied’ emissions (Fay et al. 2000) as they are not always reflected in carbon inventories or accounting tools.

This chapter critically evaluates the major standards and approaches to holistic carbon footprint accounting and reporting[4]. The definitions of the ‘indirect’ GHG emissions adopted by different standards are reviewed and discussed in the context of holistic carbon assessment at the product and service level. The applicability of the standards to carbon impact appraisal of tourism products, services and activities is assessed.

3.2. INTERNATIONAL STANDARDS FOR CARBON ACCOUNTING AND REPORTING

Sections 2.4.5 and 2.4.7 have suggested that two dimensions of ‘indirect’ GHG emissions can be distinguished. These are related to the:

1) Emissions attributed to an individual product and/or service, i.e. *product or service-specific* ‘indirect’ carbon footprint and

2) Emissions arising from operations of a company, organisation and /or business, i.e. *corporate or business-specific* ‘indirect’ carbon impacts.

The product or service-specific ‘indirect’ GHG emissions stem from the non-use phases of its life cycle, and also relate to the capital goods and infrastructure (Frischknecht *et al.* 2007a). In contrast, the corporate ‘indirect’ carbon footprint is associated with the company’s supply chain. It usually excludes the carbon impacts from the use of products manufactured by the reviewed company. These GHG emissions are assigned to product or service users as they are considered to be beyond the scope of

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[4] Only the key *public* standards are analysed. While a number of commercial industry- and/or sector-specific GHG emission standards may exist, these have not been reviewed due to their specialised nature and restricted access.

company's operations and, consequently, outside the area of corporate responsibility (The Greenhouse Gas Protocol Initiative – GHG Protocol 2011).

The corporate 'indirect' GHG emissions have been the primary focus of academic research and the key target for policy-making measures. This is because the regulatory bodies, company's shareholders and general public are imposing increasingly stricter requirements on the environmental performance of businesses which are now bound to comprehensively report on the full magnitudes of GHG emissions attributed to their activities and operations. Assessing the product-specific 'indirect' carbon footprint has gained less attention although this is changing.

A number of internationally recognised standards for accounting and reporting on the corporate and product or service-specific GHG emissions exist. These handle different dimensions of the 'indirect' carbon impacts and operate different definitions of the 'indirect' carbon footprint. The major approaches are reviewed below.

3.2.1. The Greenhouse Gas Protocol Initiative (the GHG Protocol)

The Greenhouse Gas Protocol Initiative (GHG Protocol hereafter) has been developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) and is currently broadly applied for carbon footprint assessment all over the world (GHG Protocol 2011). The GHG Protocol is particularly popular in USA where it is officially recognised as a primary GHG emission accounting and reporting tool for organisations. It provides estimates of the carbon footprint for a number of business sectors, including services. The process- or activity-specific GHG emission factors utilised by the GHG Protocol have been retrieved from a range of carbon inventories where the US Environmental Protection Agency (EPA), IPCC and DEFRA represent the major data donors (Figure 2.1).

The GHG Protocol distinguishes between the direct and 'indirect' carbon impacts from the company's operations. The 'direct' GHG emissions are released from the sources *owned or controlled* by the company under review. The 'indirect' GHG emissions result from the activities of the reviewed company, but occur at sources owned or controlled by *another* organisation (GHG Protocol 2011). Following this definition, the 'indirect' GHG emissions are often referred to as the 'off-site' carbon impacts (Lenzen *et al.* 2003).

The GHG Protocol further distinguishes three major scopes of the direct and 'indirect' carbon footprint (GHG Protocol 2011; SAS 2009):

Scope 1 relates to the direct GHG emissions arising from operating the company's equipment and 'in situ' processes and activities. The carbon footprint from vehicles owned by the company can be classified, for example, as emissions from Scope 1 (Table 3.1).

Table 3.1. The scopes of corporate GHG emissions defined by the Greenhouse Gas Protocol Initiative.

Source: GHG Protocol (2011); SAS (2009).

Scope	Type of GHG emissions	Examples
1	'Direct'	Company owned vehicles
		'In situ' fuel combustion
		'In situ' manufacturing processes
2	'Indirect'	Purchased electricity
		Purchased heat
		Purchased steam
3	'Indirect'	Production of purchased services and materials
		Employee business travel and commuting
		Leased vehicles and services
		Auto rentals
		Outsourced services
		Product or service use by consumers
		Waste disposal

Scope 2 corresponds to the 'indirect' carbon footprint stemming from the use of *purchased* energy. These 'indirect' GHG emissions are generated by third parties, such as power plants, but cannot be avoided by the company under review.

Scope 3 deals with the 'indirect' carbon impacts not covered in Scope 2. These relate to the reviewed company's processes and activities, but come from 'external' providers. The Scope 3 'indirect' GHG emissions are primarily comprised of the 'upstream' carbon footprints from the company's suppliers. This category can also include the 'downstream' 'indirect' carbon impacts produced by the company's customers using its products or services; although it is not an established practice yet to account for these GHG emissions within Scope 3 (GHG Protocol 2011). All this implies that the GHG Protocol employs the principle of input-output modeling in classifying the corporate direct and 'indirect' carbon footprint which excludes the GHG emissions from the use phase (see 2.3.3 for discussion).

The standards for carbon footprint accounting and reporting developed by the GHG Protocol recommend that only the GHG emissions from Scope 1 and 2 are to be considered in carbon impact appraisals, while addressing the GHG emissions from Scope 3 is optional. This is because the Scope 3 emissions are often hard to measure given a large number of variables required for holistic carbon footprint assessment of the supply industries (GHG Protocol 2011). Importantly, the nature of definitions and categories of GHG emissions operated by GHG Protocol suggests that these standards are most suitable for appraisal at the corporate level while their applicability at the level of individual products and services is limited.

3.2.2. International Organisation for Standardisation (ISO)

Another approach to estimating and reporting on company's GHG emissions is outlined by the ISO 14064-65 series of standards (International Organization for Standardization - ISO 2006b). These are fully compatible to the standards adopted by the GHG Protocol (Hodgson and Gore 2007). The minor difference is that they distinguish four categories (scopes) of the direct and 'indirect' corporate carbon footprint (Table 3.2).

Table 3.2. Corporate GHG emissions as categorized by the ISO 14064-65 series of standards.

Source: Hodgson and Gore (2007), ISO (2006b).

Category of GHG emissions	Sources	Optional/compulsory for accounting and reporting?	Examples
1. 'Direct'	Activities undertaken by the company and its staff	Compulsory	Operation of company-owned vehicles
			On-site fuel usage and power generation
2. Energy 'indirect'	Imported electricity, heat or steam	Compulsory	Power generation in the power plant supplying electricity to the company
3. Other 'indirect'	Company's procurement activities from sources that are owned and controlled by another company	Optional	Transportation of company's products, materials and people by vehicles operated by another company
			Business travel and commuting
			Outsourced activities, contract services
4. 'Affected' emissions	End-use and disposal of company's products and services	Optional	Utilization and recycling of cars from company's corporate fleet
			Use and disposal of a product purchased by a final customer

Table 3.2 demonstrates that the ISO 14064-65 series of standards go slightly further than the GHG Protocol as they separate the 'indirect' supply chain-related GHG emissions (category of 'other 'indirect'') from the 'indirect' final consumer-related carbon impacts (part of category 'affected emissions'). More important is that these categories of the 'indirect' carbon footprint are optional for corporate accounting and reporting. In general, they do not account for the product or service-specific 'indirect' GHG emissions, including those related to the capital goods and infrastructure.

The ISO 14064-65 series of standards do not operate a separate GHG emission inventory; they only provide general guidance on how the corporate carbon footprint is to be assessed for compliance reporting. The carbon inventory developed by the GHG Protocol can be used for making actual estimates.

Given the complexity of estimating the GHG emissions associated with categories 3-4 from the ISO 14064-65 series of standards and Scope 3 from GHG Protocol, thorough selection, reasonable justification and the transparent establishment of appropriate system boundaries is vital for holistic corporate carbon footprint auditing and reporting (GHG Protocol 2011). Businesses should ultimately aim at reducing their GHG emissions. This indirectly implies that extending the system boundary for assessment is not in company's interest as the carbon impacts from the supply side can be large, thus magnifying the overall volume of the corporate GHG emissions. However, extending the company's system boundaries to cover all scopes and categories of the 'indirect' carbon impacts can be beneficial. Inclusion of the supply chain industries in corporate carbon footprint assessment can identify a number of cost-effective opportunities for mitigating the company's overall GHG emissions. Addressing these opportunities will create a 'greener' image and should help businesses meet the increasingly more stringent legal requirements on the corporate carbon performance from the company's stakeholders and governmental regulators (Hodgson and Gore 2007). It also enables companies to have a beneficial influence on suppliers. Moreover, a broader system boundary setup for carbon footprint analysis can help the company avoid criticism related to 'green-washing' issues. All this implies that businesses should clearly list the assumptions made and the rationales applied to the setup of the system boundaries for corporate GHG emission accounting and reporting (Hodgson and Gore 2007).

3.2.3. Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) has developed guidelines for reporting on GHG emissions from a number of industrial processes and activities.

These are predominantly used for carbon impact appraisal at the national or corporate levels (Intergovernmental Panel on Climate Change – IPCC 2006). Importantly, the IPCC standards operate a different definition of the 'indirect' carbon footprint than the ones presented in sections 3.2.1 and 3.2.2. The greenhouse effect caused by some anthropogenic emissions, the so-called precursors, which may contribute to the formation of traditional greenhouse gases is referred to as the 'indirect' carbon effect (IPCC 2006). Moreover, the enhanced GHG emissions produced by aviation at higher altitudes as a result of the radiative forcing effect are also defined as the 'indirect' carbon impacts (IPCC 2006). Furthermore, the IPCC standards do not distinguish between compulsory and optional elements in corporate carbon accounting and reporting. They recommend addressing *all* carbon footprints related to company's activities and operations.

IPCC makes activity or process-specific estimates of carbon impacts on the basis of the GHG emission coefficients retrieved from a range of sources, including governmental agencies (US EPA, European Environment Agency - EEA), industry-related databases, peer-reviewed academic publications and consultations with experts (IPCC 2006). These have been summarized in a specialized IPCC emission factor database (IPCC 2010). The primary limitation of this carbon inventory is that it cannot be broadly applied as some data, such as those derived from the US EPA, are not applicable to all geographies. Another important drawback of the IPCC standards is irregular updates of its GHG emission factor database which affects the currency of carbon footprint estimates. Importantly, some carbon intensity coefficients from IPCC have been included in the basis of the GHG emission factors developed by the GHG Protocol and DEFRA (Figure 2.1). The DEFRA approach is introduced below.

3.2.4. Department for Environment, Food and Rural Affairs (DEFRA)

The UK's Department for Environment, Food and Rural Affairs (DEFRA) has developed independent standards for carbon footprint accounting and reporting, i.e. DEFRA's GHG conversion factors. They were originally designed for use by businesses in the UK but the scope of application has dramatically extended and now includes a number of other European countries and Australia and New Zealand. Until recently, the GHG conversion factors from DEFRA were capable of estimating the 'direct' carbon impacts only; since 2009 they have been revised and now account for some aspects of the 'indirect' GHG emissions (DEFRA 2010a). The GHG conversion factors from DEFRA are based on a number of data sources, including IPCC and EEA (Figure 2.1); some carbon intensity values have been derived empirically.

Similar to the GHG Protocol, DEFRA distinguishes three scopes of the corporate carbon footprint where Scope 1 and 2 are compulsory for carbon accounting and reporting and Scope 3 is discretionary. However, when applied on a product or service level, it operates different definitions of ‘direct’ and ‘indirect’ GHG emissions. These are closely related to the fuel chain and categorised as follows:

The ‘direct’ carbon footprint is defined by DEFRA as the GHG emissions produced at the point of use of fossil fuel or energy generation. In the case of electricity, for example, this is the carbon footprint arising from fuel combustion in a power plant (DEFRA 2010a).

The ‘indirect’ GHG emissions are referred to as those released *prior to* use of the fossil fuel or energy carrier. In terms of electricity production, these are the carbon impacts stemming from the processes and activities which occur before fuel gets delivered to a power plant. The GHG emissions associated with fuel extraction and its transformation from a raw resource (for example, raw gas) to the energy carrier (for instance, propane) with further intermediate storage and transportation to a final consumer are an example. This means that the estimates of the carbon footprint made by DEFRA take into account the life cycle GHG emissions from the fuel chain. Any other ‘indirect’ GHG emissions, also associated with the capital goods and infrastructure, which are not directly related to fuel are excluded (DEFRA 2010a). The feasibility of extending the scope of assessment and integrating the remaining ‘indirect’ carbon footprint into future carbon impact appraisals by DEFRA is currently being investigated (Sarah Dobbing, Policy Adviser – Corporate Reporting and Responsible Investment, DEFRA, personal communication, 15 April 2010).

There is evidence that the GHG conversion factors from DEFRA and the GHG emission standards from the GHG Protocol are inter-related (DEFRA 2010a). Apart from homogeneity in categorisation of the scopes of the ‘indirect’ GHG emissions, the GHG Protocol utilises the basic data from DEFRA for estimates of the carbon footprint from some products, services and activities, such as aviation (Figure 2.1, see Further analysis in Appendix 1 for more details), supplemented with the data from other carbon inventories. This indicates some degree of compatibility between the key internationally recognised tools for corporate carbon footprint assessment.

3.2.5. Publicly Available Specification (PAS) 2050

An attempt to combine the estimates of the ‘indirect’ corporate and product or service-specific carbon footprints in a single GHG emission accounting tool has been undertaken in the UK. The Carbon Trust together with DEFRA has appointed the British Standard Institute (BSI) to develop the Publicly Available Specification (PAS) 2050 as a comprehensive standard for measuring the embodied greenhouse gases in products and services across their life cycle (Pant *et al.* 2008). The primary objective of this project is to provide a simplified standardized approach for carbon accounting and reporting that could be used by the wider audience, is suitable for corporate purposes and covers a broad diversity of products and services (Berners-Lee *et al.* 2011; DEFRA 2008). PAS 2050 is designed as the first step towards the development of a future internationally agreed and recognised standard for organisations to estimate the GHG emissions embodied in their goods and services (Sinden 2009). The new approach has been designed as capable of estimating both the direct and the ‘indirect’ carbon footprint as it is based on the concept of life cycle assessment (British Standard Institute - BSI 2008a; DEFRA 2008; Sinden 2009).

The distinctive feature of the PAS 2050 approach is that it only provides general guidance for companies on how to assess the life cycle GHG emissions from their products and services. Similar to the ISO 14064-65 series of standards, and in contrast to the GHG Protocol, IPCC and DEFRA, it does not actually develop or operate any independent carbon inventory. In fact, PAS 2050 recommends the use of activity or process-specific GHG emission coefficients from such external sources as the peer-reviewed publications and independently verified public databases of life cycle GHG emissions. The governmental carbon inventories, such as the GHG conversion factors from DEFRA and the datasets developed by the United Nations and IPCC, are another recommended source of data in PAS 2050 (BSI 2008b). For example, for carbon footprint assessment of transportation in the UK, PAS 2050 suggests to use the GHG emission values on fuel combustion in vehicles from DEFRA (DEFRA 2008). PAS 2050 requires thorough documentation of the data sources used by the company for carbon accounting and reporting and suggests some standards for data quality assurance (BSI 2008b).

The potential of the PAS 2050 project remains unexplored. Minx *et al.* (2008 cited Berners-Lee *et al.* 2011) question its practicability and argue for its limited suitability for comparative product assessment.

Importantly, while the primary goal of the PAS 2050 standards is to provide the company's carbon footprint estimates along with the estimates of the GHG emissions from individual products and services, it has been applied predominantly at the corporate level. Holistic carbon impact appraisals of individual products and services carried out on the basis of the PAS 2050 approach are yet to be conducted. This suggests that all established international approaches to carbon accounting and reporting are limited in scope of application as none have been specifically designed to comprehensively estimate the GHG emissions for individual products or services.

3.2.6. Country-specific approaches

A number of country-specific standards for assessing GHG emissions exist. The 'Bilan Carbone' carbon footprinting software has been developed by the French Environment and Energy Management Agency (Agence de l'Environnement et de la Maîtrise de l'Energie) - ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie – ADEME 2007) for the purpose of corporate carbon accounting and reporting. The Australian Department of Climate Change is using their own GHG emission inventory for estimating the carbon impacts from Australian businesses (see Further analysis in Appendix 1 for details). The Institute for Energy and Environmental Research (IFEU) at German Federal Environment Agency has developed the GHG emission factors for mobile sources in Germany (Institut für Energi und Umweltforschung – IFEU 2008). National carbon footprint accounting and reporting standards have also been launched in Japan, South Korea and New Zealand (Finkbeiner 2009). There are no conceptual differences between these approaches and the method from DEFRA. All these methodologies are based on national statistics and data from the national industries which are further supplemented with the GHG emission factors from the IPCC, DEFRA and the GHG Protocol inventories.

The estimates produced by the nation-specific approaches are most representative of the countries where they have been developed. The application of these standards for estimating the GHG emissions in other geographical regions is limited due to the significant variance in national energy and carbon intensities. Importantly, the nation-specific standards for carbon accounting and reporting are capable of estimating the direct carbon footprint only; the 'indirect' GHG emissions are generally not addressed.

3.3. THE CAPABILITY OF THE REVIEWED STANDARDS TO ASSESS THE CARBON FOOTPRINT FROM TOURISM PRODUCTS

The analysis has demonstrated that the key standards for accounting and reporting on the GHG emissions have been designed, and are therefore primarily used, for assessment of corporate carbon impacts. The evidence of their application for carbon footprint appraisal of individual products and services is limited. Concurrently, the analysis suggests that the standards can be adapted for employment at the product and service level, including tourism. This is because they are capable of producing the estimates of the GHG emissions for a broad range of transportation means, including those related to leisure. Moreover, the carbon impact appraisal of energy use in service companies, including hotel buildings, can be made. The primary limitation of these standards is that, when applied on a product and service level, they fail to comprehensively account for the 'indirect', life cycle-related GHG emissions, including those arising from the capital goods and infrastructure. The GHG conversion factors from DEFRA are a partial exception as they are capable of estimating the 'indirect' carbon footprint associated with the fuel chain. The DEFRA's approach is however limited in terms of excluding the non-fuel chain related 'indirect' GHG emissions from assessment.

Furthermore, the analysis indicates that, among the reviewed standards, the GHG conversion factors from DEFRA can be proposed as the most suitable approach for carbon impact assessment of specific tourism products and services in Europe. It is a UK-based tool but it can also estimate the GHG emissions from energy consumption in some other European geographies. In addition, the DEFRA's factors include a broad range of leisure-related product and service categories from the transportation sector.

The GHG emission standards from the GHG Protocol are best applied to carbon impact appraisal of tourism in the USA as its estimates are predominantly based on the data from the US EPA. As the DEFRA's standards share some data with the GHG Protocol, both approaches can be applied interchangeably for assessment of specific product or activity categories, such as air travel.

The PAS 2050 approach and the ISO 14064-65 series of standards can be used as general guiding tools for making holistic carbon impact appraisals for companies and individual products and services. In turn, the actual appraisals can be carried out on the basis of DEFRA and/or the GHG Protocol as these standards are compatible with PAS 2050 and ISO 14064-65, respectively.

The IPCC standard is characterised by the irregular updates of its carbon inventory, limited geographical representation of the operated GHG emission factors and no account of the ‘indirect’, life cycle-related carbon footprint. This limits the value of the IPCC approach.

The nation-specific GHG emission standards are best applied to carbon impact appraisal in the countries where they have been originally developed. The potential of these standards to provide holistic carbon footprint assessment of tourism products and services, including the estimates of the ‘indirect’ GHG emissions, is yet unknown and needs to be established through more in-depth research and product or service-specific case studies.

3.4. SUMMARY

This chapter has critically evaluated the key approaches to holistic assessment of GHG emissions. The analysis has demonstrated that the definitions of the ‘indirect’ carbon footprint operated by the reviewed techniques vary. More important is that the capability of the established standards to appraise the ‘indirect’ carbon impacts attributed to specific products and services and arising at the non-use stages of their life cycle is limited. The primary emphasis is given to the estimates of the ‘indirect’ supply chain-oriented GHG emissions from corporate activities and operations. The product or service-specific ‘indirect’ carbon footprint is less addressed. This implies that the reviewed techniques are most suitable for assessing the *corporate* carbon impacts from tourism businesses, such as travel agents, tour operators or hotels. As one of the primary objectives of this study is to better understand the significance of the ‘indirect’ carbon footprint from a popular tourism *product*, a holiday package tour, adaptation of the method to be capable of estimating the life cycle product-specific carbon footprint is necessary. The next chapter introduces and critically reviews the applicability of Life Cycle Assessment (LCA), an established technique for appraising the environmental impacts on a product or service level, to tourism carbon footprint assessment research.

CHAPTER 4. A REVIEW OF LIFE CYCLE ASSESSMENT (LCA) AS A TOOL FOR ENVIRONMENTAL APPRAISAL OF PRODUCTS AND SERVICES

4.1. INTRODUCTION

Although the necessity to apply the life cycle approach for environmental appraisal in tourism has been repeatedly emphasised (see Gössling *et al.* 2005; Hunter and Shaw 2007), very few holistic, i.e. accounting for both direct and 'indirect' life cycle environmental impacts, assessments of tourism products, services and activities have been attempted. The primary reason is the methodological under-development of the tourism impact assessment domain where no established appraisal approaches capable of estimating the full magnitude of the life cycle environmental impacts at the product or service level exist.

This chapter introduces the Life Cycle Assessment (LCA) method which is broadly recognised as a developed technique for comprehensive appraisal of environmental impacts from products and services (Patterson and McDonald 2004). The assessment framework adopted by LCA is outlined and the benefits of its implementation in tourism are critically reviewed. Previous attempts to apply LCA in the tourism domain are examined throughout the analysis of the literature on LCA and leisure-related activities. The derivative of LCA, the Life Cycle Energy Analysis (LCEA) method, is introduced as a more specialised technique for assessing the carbon impacts from products and services.

Case studies were undertaken to test the applicability of LCEA in the field of tourism by conducting a holistic carbon footprint assessment of tourist accommodation facilities and a short holiday tour. The results are presented and the implications critically discussed. The case studies are reported in detail in journal articles (Filimonau *et al.* 2011a; 2011b, see Appendix 2).

4.2. THE METHOD OF LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is a recognised tool for evaluating the environmental performance of individual products or services throughout their lifecycle (Becken and Simmons 2008; Patterson and McDonald 2004). The concept of LCA was proposed by the Society of Environmental Toxicology and Chemistry (SETAC) in 1990s (Hertwich *et al.* 1997). Today LCA is often cited as the most appropriate, well-established and developed method for holistic environmental assessment (Junnila 2004; Ness *et al.*

2007), whose chief advantage is the structured and comprehensive approach (UK CEED 1998).

LCA can be briefly defined as an appraisal technique which identifies and quantifies the energy and material usage, evaluates the environmental releases of the given system, and further appraises the corresponding impacts on the environment (Junnila and Horvath 2003b; Koroneos *et al.* 2005). LCA has a broad international acceptance in the scientific community, also as a means to improve environmental performance of products or services and to set targets for prevention and mitigation of negative environmental impacts (Ortiz *et al.* 2009b). It is often referred to as the most suitable method for assessing and comparing materials, products and services from an environmental point of view (Arena and de Rosa 2003). LCA has been identified as a strong scientifically-grounded support tool for environmental decision-making in different sectors of the global economy (Koroneos *et al.* 2005; Paulsen and Borg 2003).

LCA has proven its analytical rigour and scientific soundness in many disciplines (Frischknecht and Rebitzer 2005). Importantly, it has been considered as a method for more thorough and comprehensive assessment of environmental impacts from the service sector companies (Junnila 2006a). Despite this, the limited evidence of the LCA application in the service sector in general, and the tourism industry in particular, exists (Junnila 2006a; Schianetz *et al.* 2007).

The explanation for the limited application of LCA to services is due to its poorly understood evaluation potential (De Camillis *et al.* 2010), assumed linearity of the natural processes (Junnila and Horvath 2003b), and often time-consuming and expensive procedure of data collection, interpretation and analysis required (Bala *et al.* 2010; Schianetz *et al.* 2007). These factors may outweigh the numerous advantages of LCA which are: transparent evaluation procedure, rigorous analysis, 'prospective' assessment of alternatives, and minimization of risks of overlooking important environmental aspects of the appraised products and services (Patterson and McDonald 2004; Schianetz *et al.* 2007). At the same time, it is recognised that the lack of application of LCA in the service sector hinders the effective environmental management of service companies as the quantitative impact indicators produced by existing methods for environmental assessment of services have limited application (Junnila 2006a). Exclusion of the life cycle perspective from assessment of environmental impacts from products and services may lead to inaccurate conclusions (Hertwich *et al.* 1997).

A distinctive feature of LCA is the flexibility of design that allows future scenario and sensitivity analyses to examine different alternatives (Ally and Pryor 2007; Paulsen and Borg 2003). This is vital as all environmental assessment tools are influenced by the hypotheses and assumptions made when defining the goal and scopes of future research as well as when performing the data collection and analysis. A sensitivity analysis helps identify factors and input parameters which affect the final results to the greatest extent (Blengini 2009). This implies that the LCA-based environmental assessments highlight both existing and potential environmental issues in the system under review, and also help explore how available policy options and management frameworks should be refined to encourage impact reduction (Thollier and Jansen 2008).

Another important feature of LCA is that it provides a sound basis for assessing the hidden 'indirect' or embodied, life cycle-related, environmental impacts from products and services (Berners-Lee *et al.* 2011; Frischknecht *et al.* 2007a) which are significant but rarely addressed in the literature (Chwieduk 2003; Patterson and McDonald 2004). The life cycle GHG emissions are estimated by specialized research groups for a broad range of products and services and summarized in the form of extensive life cycle inventories (Koroneos *et al.* 2005), such as the Ecoinvent database (Frischknecht and Rebitzer 2005). The content of these databases gives an option of inclusion or exclusion of the 'indirect' environmental impacts of various components associated, for example, with the infrastructure and capital goods (Frischknecht *et al.* 2007a). As LCA appraises the environmental impacts from products and services starting with the 'birth' (manufacturing) stage and up to the 'death' (final disposal) phase, the assessment principle it relies upon is referred to as the 'cradle-to-grave' concept (Baumann and Tillman 2004).

LCA can help estimate the 'indirect' environmental contribution from the 'upstream' supply chain industries. Although some authors argue that a traditional LCA can capture less than 50% of the total 'indirect' environmental impacts, predominantly related to the first-, second-, and third-orders of suppliers (see, for example, Berners-Lee *et al.* 2011; Foran *et al.* 2005), the alternative environmental assessment tools are either not capable of addressing the 'indirect' environmental impacts at all or are limited to the evaluation of first-order suppliers (Lundie *et al.* 2007). This is fraught with significant underestimates of the overall environmental impact (see 2.4.7 for discussion). Moreover, the hybrid economic-environmental IOA method, which is able to fully expand the extent of analysis to account for all the 'indirect' environmental impacts from suppliers can only be utilised at large scales, such as national economies and specific industries (Hendrickson *et al.* 1998). In contrast, LCA is suitable for smaller scales of evaluation, i.e. on the level of individual products and services (Foran *et al.* 2005). While accounting for only few levels of suppliers may result in (up to 50%) underestimation of the total environmental impacts (DEFRA 2008), the LCA-based estimates are more accurate and conduct a more holistic analysis than the estimates from any other environmental appraisal tools applied in the service sector at the product level. This implies that LCA is a promising solution to tackle the large diversity and magnitude of the 'indirect' environmental impacts associated with the supply chain, given the mediocre quality of existing environmental assessment methods. With these advantages, it is argued that LCA should be broader applied to appraisal of environmental impacts from services, including tourism.

Importantly, In terms of the scope of application, LCA is a flexible technique. It can be applied to environmental assessment of products and services in different localities as it handles a number of impact factors representative of the European Union (EU) countries and North America.

4.2.1. The methodological framework for assessment in LCA

The methodology for conducting a LCA for individual products and services has been internationally appraised and reflected in the ISO 14040 series of standards (ISO 2006a). According to ISO, LCA consists of four distinctive stages (Figure 4.1):

1) *Goal and scope definition* which explains the study purpose, defines a functional unit for analysis, and sets up system boundaries;

2) *Lifecycle inventory* that involves data collection and systematization;

3) *Impact assessment* which evaluates the magnitude of environmental burdens and

4) *Interpretation* of results which draws conclusions and provides recommendations for environmental improvements.

All data in LCA are related to a basis for comparison, the functional unit (Paulsen and Borg 2003). It is defined as the quantified performance of a product or service (Jonsson 2000). In terms of tourist accommodation facilities, for example, '1 guest night stay in a hotel' with associated environmental impacts can serve as a functional unit for analysis.

For leisure transport, '1 km driven by a passenger car' is another example of a functional unit.

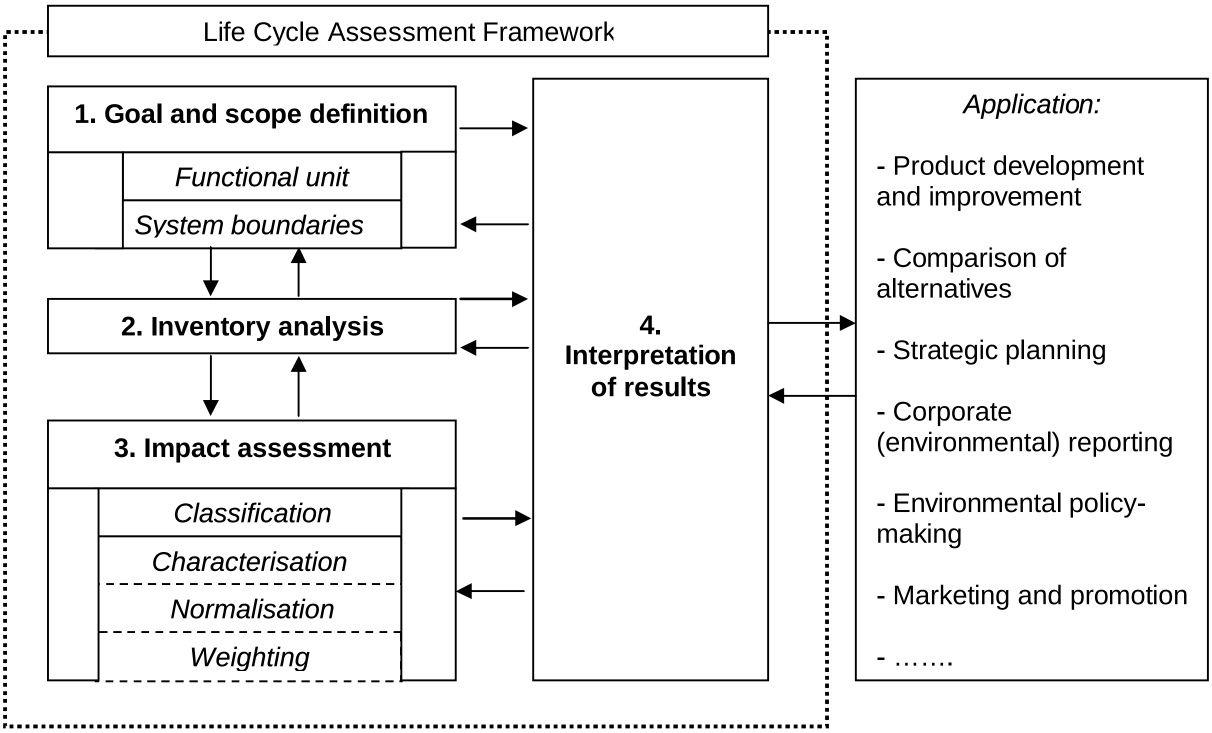


Figure 4.1. Major stages and possible applications of LCA.

Source: adapted from ISO 14040 (2006a).

Precise definition of system boundaries, i.e. processes included and excluded from analysis is a distinctive feature of the LCA methodology (Kellenberger and Althaus 2009; Peuportier 2001). Although the setup of system boundaries for LCA usually involves a subjective element (Berners-Lee *et al.* 2011), it is argued that this issue is typical not only for LCA, but also for alternative impact assessment techniques.

Importantly, the general framework of impact assessment adapted by LCA (stage 3) consists of four structural elements: classification, characterisation, normalisation and weighting. The ISO 14040 series of standards prescribe that the classification and characterisation steps that convert the impact assessment outcome into an easy-to-understand quantitative indicator for specific impact categories (for example, kg of CO_2 produced) are mandatory elements of assessment, while normalisation and weighting that lead to a unique indicator across all impact categories, showing the relative significance of each specific impact are discretionary (Blengini 2009; ISO 2006a).

4.2.2. Categorisation of LCA

Two major categories of LCA can be distinguished: the process-based LCA and the input-output LCA (Hendrickson *et al.* 1997; Lenzen 2000). The input-output LCA represents a derivative of the large-scale economic input-output assessment (IOA) technique (see 2.3.3 for overview) which is generally applied at 'macro' levels, such as national industries and economic sectors (Junnila 2006b). The process-based LCA is a conventional form of environmental life cycle analysis carried out on a 'micro' level of specific products and services.

There is no agreement in the literature about which category of LCA provides more accurate assessments. There is evidence that the input-output LCA generates higher estimates of environmental impacts (Hendrickson *et al.* 1997; Junnila 2006b; Lenzen 2000; Lenzen and Dey 2000), and therefore also greater impacts with regard to climate change (Fthenakis and Kim 2007). The necessity to further analyse the discrepancies in appraisals produced by different categories of LCA is acknowledged (Fthenakis and Kim 2007). The lower estimates of environmental impacts made by the process-based LCA are arguably because of the truncation errors (Lenzen 2000; Lenzen and Dey 2000). The process-based LCA fails to account for *all* environmental contributions on the higher (upstream) orders of a product system as these can be of infinite order (see 4.2. for discussion). Hence, there will be a bias as there are always additional or yet unknown processes that will be overlooked (Berners-Lee *et al.* 2011). The omission of some upstream processes is the primary reason for truncation errors (Nässen *et al.* 2007); hence, their occurrence is inevitable when the process-based LCA method is applied (Berners-Lee *et al.* 2011). Nonetheless, the input-output LCA is also not perfect (see 2.3.3); therefore, to address the shortcomings of the two methodologies, a 'merged' LCA, i.e. a combination of the process-based LCA and the economic input-output LCA, has been proposed (Lenzen 2000). While more holistic and, arguably, more accurate in nature of analysis, this method is still being developed and its feasibility for assessment of specific products and services needs to be tested (Berners-Lee *et al.* 2011). The development of the 'combined' LCA is not advanced enough to be considered by this research.

4.3. APPLICATION OF LCA IN TOURISM

There is limited evidence of the application of LCA for assessment of environmental impacts from tourism (De Camillis *et al.* 2008; Raggi *et al.* 2008; Schianetz *et al.* 2007). Only seven original studies have been found in the public domain: four of these have employed the traditional process-based LCA, whereas the remaining three have used a hybrid, economic–environmental input–output LCA analysis.

The focus of the hybrid LCA is on a rather large scale, i.e. the national tourism industry (Patterson and McDonald 2004) and its particular sectors (Rosenblum *et al.* 2000). Berners-Lee *et al.* (2011) applied this technique on a corporate level for carbon impact appraisal of a large tourism company.

The process-based LCA has been employed in tourism assessment research on a smaller scale. Kuo *et al.* (2005a) assessed the environmental performance of meal boxes in tourism catering. Although clearly related to tourism, this study does not however address the totality of holiday travel. König *et al.* (2007) conducted LCA of a holiday resort under development. This review cannot be considered complete, as the environmental impacts of the resort operations have been modeled, but not measured directly. De Camillis *et al.* (2008) and Sara *et al.* (2004) applied LCA to hotels in Italy. Unlike the previous case, hotel operations have been appraised and their environmental impacts quantified. Nonetheless, the 'indirect' environmental impacts, also those arising from construction of the hotel building and manufacture of the hotel equipment, have been excluded. More research on LCA in tourism has been conducted in Italy (see De Camillis *et al.* 2010, for an overview), but its outcome is not in the public domain.

Some research has emphasized the need to apply the life cycle perspective in tourism but did not directly use the LCA method. World Wild Fund–UK (2002) and Chambers (2004) employed, for example, the life cycle approach but not the original LCA methodology to an EFA of holiday packages. The environmental assessments conducted by the UK CEED (1994, 1998) are also based on the life cycle perspective rather than on a full-scale LCA analysis; in addition, they are qualitative in nature, incomplete with regard to consideration of all phases of tourism product's life cycle, not widely available and lacking in detail (Chambers 2004). Kuo and Chen (2008, 2009) applied a life cycle approach to quantify the environmental loads from island tourism. This study assessed the environmental impacts associated with travel to/from the island along with tourist accommodation and activities in the island which have been defined as the life cycle elements of tourist trips. However, the original LCA method has not been applied and the 'indirect' GHG emissions arising from tourism in the island, such as those related to the capital goods and infrastructure of specific holiday travel elements, have been excluded from analysis.

The name of LCA has appeared in some research but the original methodology has never been applied for analysis. Martins-Swan (2001), for example, developed an interactive tool for qualitative description and self-evaluation of impacts generated by sustainable tourism projects throughout their life frame and called it the 'life-cycle assessment'. In reality, this approach has limited connection to the original LCA as an established method for environmental assessment of products and services.

Efforts have begun to address the need for LCA in tourism research. For instance, the Italian LCA Network established a separate Working Group on Tourist Services that has been active since late 2007 and whose primary focus has been on LCA in the accommodation sector. To date the achievements of this group include three case studies carried out for hotels with further plans to extend the scope of LCA application to cover the most significant types and components of Italian tourism (Raggi *et al.* 2008).

Despite the recent progress made in applying LCA in tourism, no evidence of utilization of an original LCA analysis on a holiday package level has been found in the literature. The application of LCA would be useful for designing policy measures and encouraging business actions to mitigate the environmental impacts from these popular tourism products. The outcome of LCA appraisals can be communicated to the general public to provide tourists with scientifically grounded and easy-to-understand recommendations on how to check the environmental burdens of their holiday choices. Environmental assessments of holiday packages and their specific elements, based on the LCA methodology, may contribute towards creation of inventories of the most and least environmentally responsible holidays. This, in turn, may serve as a basis for further development of an eco-label which could be awarded to the most sustainable holiday packages, thus informing tourists and influencing their purchasing decisions. This is of particular relevance given that most eco-labels are based on life cycle considerations (Sasidharan *et al.* 2002) and that holiday package tours are often regarded as one of the most suitable objects for eco-certification in tourism (Budeanu 2007).

4.4. LIFE CYCLE ENERGY ANALYSIS (LCEA) AS A DERIVATIVE OF LCA SPECIALISED IN ENERGY AND CARBON IMPACTS

Applying LCA in the tourism domain can be particularly beneficial when estimating its contribution to global carbon footprint. The literature review has shown that no universal technique exists to establish the magnitudes of tourism impacts on climate.

The hidden 'indirect' carbon footprints from tourism products and services are of special concern as they represent the 'grey' area in tourism impact assessment where more empirical knowledge is required. LCA has the potential to rectify this. In addition, LCA has been specifically designed to account for *global*, rather than local or site-specific, environmental impacts occurred, for instance, in the form of GHG emissions (Hertwich *et al.* 1997; Jonsson 2000). This notwithstanding, no specialized carbon footprint appraisals of tourism products and services have been carried out using LCA.

The partial reason is that, despite the comprehensiveness of the original LCA method, direct application of this technique in the tourism sector can be difficult. Detailed LCA requires extensive analysis as it operates a broad range of impact categories (Frischknecht *et al.* 2007a). This can divert attention from the key environmental issues related to the tourism products and services life cycle. Employment of a simplified LCA method which focuses on the most environmentally significant issues in tourism can therefore be a more realistic alternative.

Importantly, the international standards for carbon accounting and reporting recognize the value of LCA analysis. DEFRA underlines the necessity to integrate the life cycle considerations into carbon impact appraisal of products and services (DEFRA 2010a). The assessment approach adopted by PAS 2050 is directly based on the concept of LCA emphasizing the accuracy and comprehensiveness of its application at a product and service level (DEFRA 2008).

4.4.1 Simplified LCA as a tool for holistic environmental appraisal

Due to the complexities of LCA and issues in data collection, a number of simplified LCA-based methods have been developed, aiming to provide quick but cost-effective analysis and to support decision-making (Menzies *et al.* 2007). The simplified LCA methods are a good solution when, for example, the available resources and quality of the obtained data are not sufficient for a rigorous LCA (Arena and de Rosa 2003).

The simplified LCA methods are based on the 'screening' and 'streamlining' approach, using a reduced inventory of the system under review and identifying only the most critical processes or 'hot spots' (Svensson and Ekvall 1995 cited Menzies *et al.* 2007). These 'hot spots' are subject to further and fuller analysis and some processes with minor contributions are eliminated or estimated (Menzies *et al.* 2007). This method allows a researcher to draw reliable conclusions, with acceptable uncertainties, but concurrently results in significant savings of research budgets and time (Arena and de

Rosa 2003; Hertwich *et al.* 1997). Given that the quantity and quality of data are often not sufficient for assessment of tourism environmental impacts (see 2.2 for discussion), it is argued that the simplified 'screening' LCA method can be employed in tourism instead of a full-scale original LCA.

4.4.2 Life Cycle Energy Analysis (LCEA) as a simplified LCA method

The primary goal of LCA is to evaluate the *overall* impact of a product or service under review; the assessment is truly holistic since it handles a range of different environmental impact categories, such as climate change, resource depletion, human toxicity, ozone layer depletion, eutrophication, acidification, aquatic eco-toxicity, ionizing radiation, photochemical smog formation (Frischknecht *et al.* 2007a; Menzies *et al.* 2007). However, as the contribution of tourism to climate change is the focus here, this has direct links to energy use with associated GHG emissions, the application of the full-scale, multi-impact conventional LCA is not rational. A simplified derivative of LCA, Life Cycle Energy Analysis (LCEA), can therefore be a good alternative.

LCEA is based on the original four-step LCA methodology but it focuses on energy and consequent GHG emissions as the only measure of environmental impacts (Fay *et al.* 2000; Huberman and Pearlmutter 2008). Similar to the traditional LCA, the backbone of LCEA is represented by the lifecycle inventory, where energy flows within the system under review are identified and quantified. The impact of these energy flows is assessed by converting the energy use data into GHG emissions (Huberman and Pearlmutter 2008; Menzies *et al.* 2007). LCEA has not been developed to replace conventional LCA (Fay *et al.* 2000); instead, it has been designed to present a more detailed analysis of energy for those products and services whose principal environmental impacts are known to stem from energy consumption (Menzies *et al.* 2007). Although the employment of such a single impact indicator can be criticized, as it ignores other environmental burdens from tourism (for example, its contribution to acidification and eutrophication), it is nevertheless deemed to be valid for usage in the context of tourism and climate change studies. It is simple, focuses on carbon impacts and is easy-to-understand for non-professionals.

4.5 TESTING THE APPLICABILITY OF LCEA IN TOURISM: THE RESULTS OF THE CASE STUDIES

To demonstrate how LCEA can be applied in the tourism domain, its assessment framework has been used to appraise the carbon impacts from two hotels in Poole, UK. Tourist accommodation has been selected as the primary testing grounds because the literature review has not identified any LCEA-based studies carried out in the hotel sector (Table 4.1). This pilot case study of hotels in Poole was required to identify the data requirements for LCEA of hotels, to better understand the appraisal methodology and to refine the assessment skills.

The LCEA case study has empirically appraised the carbon impacts from operational energy consumption of the two hotels. Estimates of the non-operational GHG emissions embodied in the hotel buildings were also made. An approach to assessing the carbon footprint from outsourced laundry and breakfast services in hotels was also proposed. The case study was reported in a journal article (Filimonau *et al.* 2011b, see Appendix 2).

4.5.1 Operational versus embodied energy and GHG emissions in hotels

In order to perform LCEA of tourist accommodation facilities, it was necessary to identify the critical aspects of energy use, i.e. the largest contribution to the total life cycle energy requirements. This was achieved by reviewing literature on environmental performance of the building stock, with a focus on tourism. It is acknowledged that the comparison of values on energy consumption as attributed to different phases of the hotel lifecycle can be criticized as the cases presented in literature vary in geography, climatic conditions, hotel type and size, estimated life frame of the hotel building and its specific components, and data sources. As the 'indirect' embodied energy and consequent GHG emissions in hotel buildings is the most challenging issue to address, the intention of the case study was to assess the *relative* importance of the operational and non-operational (embodied) hotel's energy requirements and compare them with other studies. A similar approach has been employed in the study by Sartori and Hestnes (2007).

Table 4.1. Studies on energy and environmental performance in the tourist accommodation sector.

Source	Object and location	Scope and/or research method	GHG emissions
Beccali *et al.* (2009)	Hotels in Sicily, Italy	Energy and environmental audit	Yes
European Commission (2001)	44 hotels in Cyprus, Greece, Italy, Portugal, Sweden and Germany		Partially
Chan (2005)	Hotel sector in Hong Kong	Environmental costs of energy usage, water consumption and solid waste disposal	Partially
Chan and Mak (2004)	10 hotels in Hong Kong	Environmental audit of diesel oil consumption	Yes
Chan and Lam (2002a)	11 hotels in Hong Kong	Environmental audit of gas consumption	Yes
Dascalaki and Balaras (2004)	4 hotels in France, Greece, Italy and Spain	Energy and water audits	Yes
Khemiri and Hassairi (2005)	3* hotel in Tunis, Tunisia		Partially
Deng (2003)	36 quality hotels in Hong Kong		No
De Camillis *et al.* (2008); Sara *et al.* (2004)	3 budget hotels in Italy	Full scale, multi-impact Life Cycle Assessment (LCA)	Yes
König *et al.* (2007)	Tourism resort under development in Portugal		
Scheuer *et al.* (2003)	University building with hotel functions		
Deng and Burnett (2000, 2002); Lam and Chan (1994)	17 hotels in Hong Kong	Energy audit	No
Karagiorgas *et al.* (2006)	200 hotel units in Greece, Italy, France, Spain, Portugal		
Karagiorgas *et al.* (2007)	10 hotels in Greece		
Papamarcou and Kalogirou (2001)	Luxury hotel in Cyprus		
Priyadarsini *et al.* (2009)	29 quality hotels in Singapore		
Santamouris *et al.* (1996)	158 hotels in Greece		
Ali *et al.* (2008)	80 hotels in Jordan		
US EPA (2005)	> 1000 hotels in USA		
Moiá-Pol *et al.* (2005)	About 250 hotels in Balearic Islands (Spain)		Partially
Onut and Soner (2006)	32 quality hotels in Antalya, Turkey	Survey on energy, water and liquefied petroleum gas (LPG) consumption	No
Chan and Lam (2002b)	17 hotels in Hong Kong	Survey on electricity consumption	Yes
Ronning and Brekke (2009)	149 hotels in the Choice Hotels Scandinavia group		
Trung and Kumar (2005)	50 tourist accommodation facilities in Vietnam	Survey on energy and water consumption, waste generation	No
Xydis *et al.* (2009)	4 hotels in Greece	Comparative analysis of energy efficiency	No

The literature demonstrates that, although new buildings become more efficient in energy consumption during their operation (Dimoudi and Tompa 2008; Miller 2001; Yohanis and Norton 2002), the contribution of the operational energy to the total energy use of the building stock remains dominant (Blengini 2009; Scheuer *et al.* 2003). The analysis of 60 cases focusing on residential and non-residential buildings (Sartori and Hestnes 2007) shows that operational energy represents the principal source of energy demand in a building over its lifecycle. There is further evidence that in conventional residential and commercial buildings operational energy use and consequent GHG emissions hold by far the largest share of the total building's lifecycle energy consumption and carbon footprint, with a contribution of up to 90-95% (Blengini 2009; Maddox and Nunn 2003; Sartori and Hestnes 2007). Hotel buildings are no exception (Ronning and Brekke 2009).

The operational carbon footprint of a commercial building is predominantly associated with energy consumption in the form of heating, ventilation and air-conditioning (activities known as HVAC), use of elevators (activities known as vertical transportation), use of electric appliances and lighting the building (Deng and Burnett 2002; Ortiz *et al.* 2009b; Perez-Lombard *et al.* 2008; Scheuer *et al.* 2003). In the hotel sector these activities may account for up to 85% of the total energy use (Santamouris *et al.* 1996). For example, depending on the geographical location, HVAC services may be responsible for up to 50% of total energy costs (Baker 2005 cited Sloan *et al.* 2009) and for over 60% of total energy use in tourist accommodation facilities (see, for example, Karagiorgas *et al.* 2007, Lam and Chan 1994). Lighting may account for up to 7-30% of the total electricity consumption and 25-30% of the total energy costs in hotels (Bohdanowicz *et al.* 2001a; European Commission 2001; European Commission 1994 cited Dascalaki and Balaras 2004, Greenhotelier 2003 cited Sloan *et al.* 2009, Lam and Chan 1994). Air-conditioning may represent a particularly significant share in the energy use and GHG emissions from buildings, especially in warm climates (see, for example, Adelaar and Rath 1997, Deng and Burnett 2000, Xing *et al.* 2008). Evidence shows that in tourist accommodation facilities air-conditioning systems may increase the annual energy use by 29-77% (Ali *et al.* 2008; Bohdanowicz and Martinac 2007; Deng and Burnett 2002; Santamouris *et al.* 1996).

Other operational burdens of the building stock arise from cooking in catering facilities, refrigeration, water supply, water heating, laundry, wastewater treatment and solid waste generation (Scheuer *et al.* 2003; Xydis *et al.* 2009). Due to the poor quality of data, waste issues are usually beyond the scope of analysis in environmental assessments of buildings, including tourist accommodation facilities (Sloan *et al.* 2009).

As for other operational activities, there are different estimates of their contribution. The share of hot water production, for example, is estimated as high as 40% (Deng 2003) and as low as 3-3.5% (Scheuer *et al.* 2003) of the total energy use and GHG emissions generated during the lifecycle operations of a hotel. This may be a result of variations in hotel organization. Laundry in tourist accommodation facilities, for example, can be either in-house or outsourced; in-house laundry may significantly increase the final energy requirements of a hotel (Bohdanowicz and Martinac 2007). Ali *et al.* (2008) have shown, for instance, that in-house laundry accounts for almost 55% of the total thermal energy use in Jordanian hotels.

Literature provides no information on energy demand in the building stock for cooking and refrigeration. The primary reason for this may stem from the assumption of a low contribution of catering services to the total energy use of buildings. As for tourism, evidence exists that such an assumption may be incorrect and that catering services may consume up to 15% of the total energy in tourist accommodation facilities (EIA 2003 cited Perez-Lombard *et al.* 2008, European Commission 1994 cited Dascalaki and Balaras 2004, Greenhotelier 2005a cited Sloan *et al.* 2009) with the maximum reported value of 25% (Ali *et al.* 2008; Bohdanowicz *et al.* 2001a; Thermie Programme Action 1995 cited European Commission 2001). This case study of tourist accommodation in Poole, UK, estimates the relative share of outsourced catering and laundry energy requirements and associated GHG emissions in the total energy use of hotels.

Embodied energy may also account for a substantial portion of the total energy consumption during the building lifecycle (up to 40-60%). This is due to a broad range of processes involved in the non-operational stages (Figure 4.2). However, this is mainly applicable to the low-energy housing (Atkinson *et al.* 1996 cited Yohanis and Norton 2002; Fay *et al.* 2000; Sartori and Hestnes 2007; Thormark 2002, Thormark 2006), well-insulated buildings located in harsh climatic conditions, like deserts (Huberman and Pearlmutter 2008), and traditional buildings in developing countries (Metz *et al.* 2007).

As for conventional building stock, the literature provides limited and controversial evidence of the contribution of embodied energy to the total energy requirements of these buildings. Some studies claim that the share of embodied energy may be as high as 67 times the annual operational energy consumption in an office building (Scheuer and Keolian 2002 cited Huberman and Pearlmutter 2008), or up to 30-40% of the total energy requirements in residential buildings (Cole and Kernan 1996 cited Yohanis and Norton 2002; Treolar *et al.* 2002 cited Sartori and Hestnes 2007). However, such evidence is singular and often based on obsolete data.

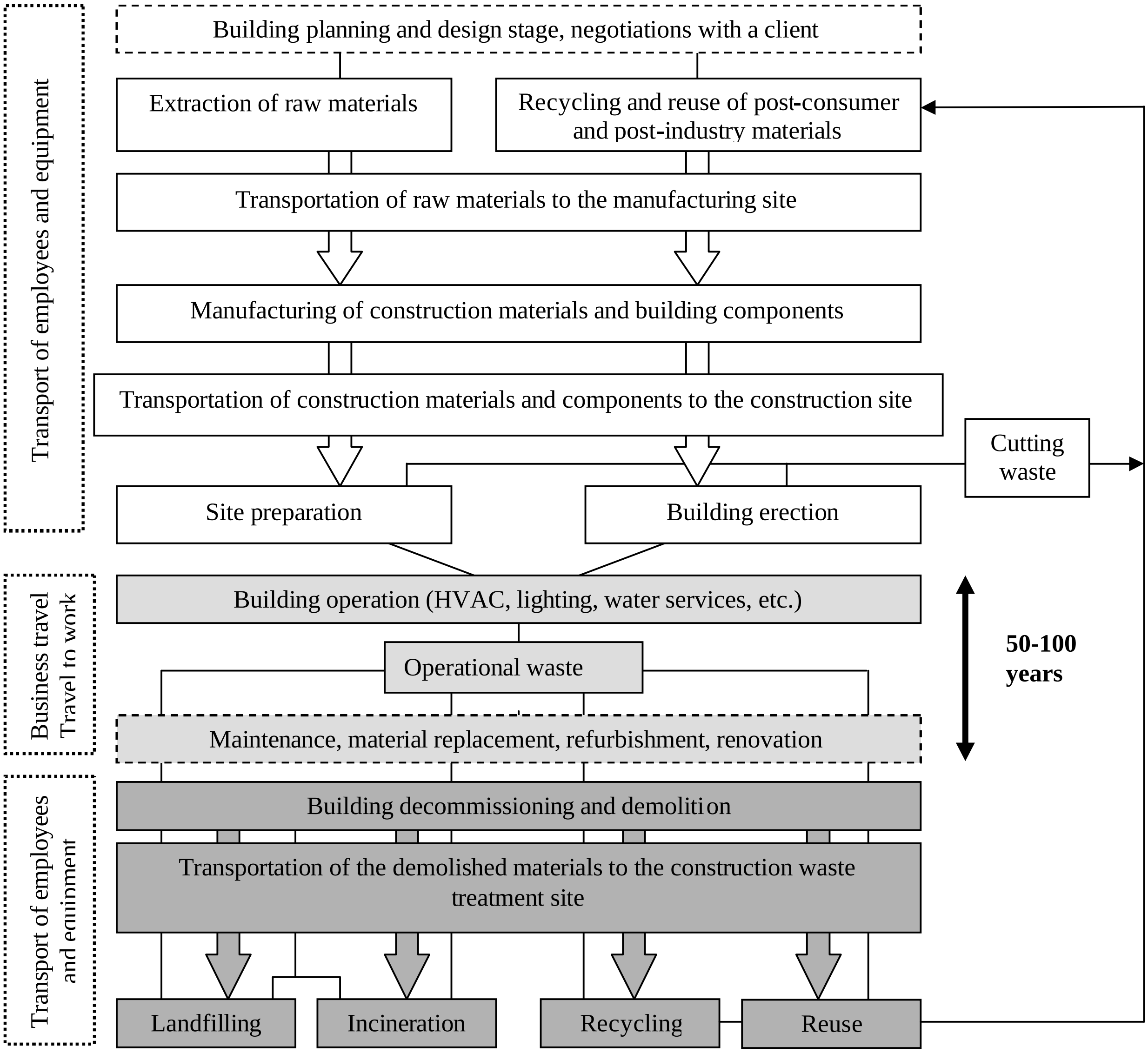


Figure 4.2. A simplified lifecycle diagram of a (hotel) building.

Source: modified from Scheuer et al. (2003) and Kellenberger and Althaus (2009). The white colour represents the pre-operational phases of the hotel building lifecycle (so-called preparation and material placement). The light grey colour corresponds to the hotel building's operations. The dark grey color indicates the end-of-life stages of the hotel building life frame.

The majority of authors are more modest in their estimates (Huberman and Pearlmutter 2008). The most common approach considers the share of embodied energy as 10-15%, sometimes up to 20%, of the total energy use in most of the conventional residential and commercial buildings within their lifecycle of 50-100 years (Blengini 2009; Dimoudi and Tompa 2008; Harris 1999; Huberman and Pearlmutter 2008; Kellenberger and Althaus 2009; König *et al.* 2007; Peuportier 2001, Sartori and Hestnes 2007; Thormark 2006). One of the constraints to more precise estimates lies in the lack of assessment methodologies and difficulties in data procurement (Huberman and Pearlmutter 2008). This makes it difficult to draw useful generalisable conclusions (Yohanis and Norton 2002). The values vary from study to study due to different backgrounds and appraisal approaches applied (Dimoudi and Tompa 2008; Kellenberger and Althaus 2009, Kohler *et al.* 1997; Yohanis and Norton 2002). Last but not least, the estimates of the embodied energy requirements are a geography-dependent variable (Harris 1999).

Among the different types of embodied energy, the energy requirements for building maintenance and refurbishments can be high as a result of their frequent applications (Thormark 2006), the long lifespan of specific buildings (Kohler *et al.* 1997), difference in the lifetime of building's structural components, (Harris 1999), and the age of the building stock (Haapio and Viitaniemi 2008). There is evidence that refurbishment periods are getting shorter for commercial buildings (Miller 2001); and hotels are no exception (Langdon 2002).[5] Complex environmental assessment of maintenance and refurbishments of the building stock is however cumbersome and the limited knowledge on how to handle these activities is recognized (Harris 1999; Kohler *et al.* 1997; Paulsen and Borg 2003).

The evidence on the contribution of embodied energy and carbon footprint to the overall energy and carbon requirements of tourist accommodation facilities is limited. König *et al.* (2007) have found, for example, that the amount of energy necessary to construct a hotel in Portugal equates to 20% of the total energy consumption of the hotel building within its operational life cycle of 80 years. The authors acknowledge, however, that this value varies with climatic conditions and may be significantly lower in some geographies (König *et al.* 2007). No further estimates are available in the literature for the embodied energy in hotels for a comparative analysis.

[5] Hotel refurbishment schemes fit into two broad categories, depending on the extent of work involved. Refreshments include redecoration of guestrooms, replacement of furniture and equipment, and minor works to improve ease of hotel operation. Remodelling/rebranding means creating new guestrooms, changing existing guestroom layouts, replacement of bathrooms, furniture and equipment, and introducing new guest services and facilities (Langdon 2002).

To summarise, existing energy audits and environmental appraisals of hotel buildings, including those based on the LCA methodology, argue that the operational energy consumption is the largest contributor to their total energy use and associated carbon footprint. The operational energy use is therefore the primary target for reducing environmental impacts associated with the hotel buildings. Embodied energy is to be addressed in the second instance (Maddox and Nunn 2003; Sartori and Hestnes 2007). The literature shows that an additional value of 15% of the operational energy use and consequent GHG emissions may fairly represent the share of the 'indirect' impacts of hotel buildings in the form of embodied energy. Such an estimate can be criticized as being too crude; hence, it is argued that it should only be used for a *sensitivity analysis*, to test how the inclusion of the embodied carbon footprint may alter the overall carbon intensity of hotel stay and/or holiday travel.

4.5.2 Goal and scope of LCEA for case study hotels

Following the methodological framework adopted by LCEA for appraising the carbon impacts from products and services, an appropriate functional unit needs to be selected for analysis. The function of hotels can be defined as 'providing accommodation to guests for a given period of time'. Hence, the energy consumption (in kWh or MJ) and associated GHG emissions (in kg CO_2-eq.[6]) per 1 guest night stay has been used as a primary benchmarking indicator of energy use and a functional unit for LCEA analysis. This has been selected for three reasons. First, calculations on a 'per capita' basis are claimed to be more reliable for evaluation of energy use intensity and consequent environmental impacts than other indicators proposed so far (Karagiorgas *et al.* 2007). Second, this is deemed to be more appropriate if environmental impacts of the entire holiday package, of which hotels are an important element, are to be assessed in the future. Third, such an indicator has been rarely employed in the literature on energy use and the environmental burdens imposed by the tourist accommodation sector (Chan and Lam 2002b; Deng and Burnett 2002) despite its ability to provide an insight into the individual contribution of hotel guests to the total energy requirements and carbon footprint of hotels.

Importantly, most existing studies have used another indicator, the annual energy use (and consequent GHG emissions) per unit of the building's Gross Floor Area (GFA)

[6] Carbon dioxide equivalents are used to calculate the cumulative impact of all GHG gases, thus serving a single unit of measurement (Kelly and Williams 2007). For example, the impact of a tonne of CH_4 is estimated as equal to 25 times the atmospheric impact of one tonne of CO_2; hence it is expressed as '25 CO_2-eq.'

(expressed in kWh or MJ/m^2/annum).[7] This is the so-called energy use intensity or energy use index (EUI) coefficient (Deng and Burnett 2000; Deng and Burnett 2002; Kelly and Williams 2007). Despite recent criticism about the adequateness of its application (Chan 2005), this indicator is still broadly employed in the building sector for energy use performance assessments (Deng 2003; Priyadarsini *et al.* 2009), as it provides a valuable insight into the building's overall energy consumption, accounting for seasonal variations (Chan and Lam 2002b). Therefore, for comparability and representativeness of results, EUI has been selected as an additional benchmarking indicator. Hence, 1 m^2 of the hotel floor area has been chosen as an additional functional unit for LCEA analysis of the case study hotels.

For better comparability, the case study selected two hotels of the same category (3*) and geographical location (city), with similar annual occupancy rates (around 90%) and room numbers (around 85). Both hotels provide a basic range of services to its guests, although catering and laundry services are outsourced. The reviewed hotels use identical types of energy (electricity and natural gas). The only differences arise from the hotels' GFA (one hotel is about 60% larger than the other) and the variety of energy-related services provided to hotel guests. The larger hotel uses air-conditioning in hotel rooms and lifts in communal areas.

The case study did not aim to analyse how the hotel building components have been produced, transported to the building site and assembled. Also it did not aim to study the infrastructure which supports the building sector. The 'indirect' embodied energy and associated carbon footprint of the hotel buildings were assumed as equal to 15% of the total operational energy requirements within the buildings' lifecycle as concluded from the literature.

In contrast to the crude assumption applied to estimating the 'indirect' energy requirements of the hotel buildings, the operational energy flows in the reviewed hotels were thoroughly analysed. The 'indirect' energy and GHG emissions embodied in the energy-related capital goods and energy production system infrastructure were accounted for.

Although the case study hotels outsource laundry and catering, the operational energy consumption and associated GHG emissions from these services have been included

[7] The following conversion factor is used: 1 kWh = 3.6 MJ (Thormark 2002).

in analysis. This has been done to better understand how accounting for these supply side services alters the overall carbon footprint from a hotel stay.

Following the guidelines of DEFRA, the GHG Protocol and ISO (see section 3.2), business travel and commuting of employees can be accounted for in environmental assessment of service companies, including tourist accommodation facilities, although there is no clear agreement in the literature upon whether or not these activities should be taken into consideration (Ronning and Brekke 2009). Evidence exists that business travel and commuting of employees may account for up to 35% of the total GHG emissions from a service company (Junnila 2004) and for about 30% of the total GHG emissions from tourist accommodation facilities (Ronning and Brekke 2009); such estimates are however singular as the data for analysis are difficult to obtain (Ronning and Brekke 2009). This study therefore did not include the carbon impacts arising from business travel and everyday commuting of the hotel staff as this information was not available. Likewise, transportation of guests to and from the hotels under review has also been excluded due to the lack of data. It is however acknowledged that the contribution of customer travel to the total GHG emissions from tourist accommodation can be significant (see, for example, De Camillis *et al.* 2008; del Pino *et al.* 2006 cited Ronning and Brekke 2009). Graphical presentation of the system boundaries established for the case study is given in Figure 4.3.

4.5.3 Data requirements for LCEA of hotels

Energy bills provided by hotel managers were the primary sources of data for LCEA analysis of the reviewed hotels. From these, information on the total annual energy consumption was extracted. Importantly, the case study showed that some hotels might not have direct access to the values on their energy usage. One of the hotels (further referred to as Hotel 2 in this case study) had all energy bills sent direct to the head office located in London. The hotel manager had to request the data on energy consumption from the head office. In contrast, Hotel 1 had all energy bills sent directly to the hotel in Poole.

To estimate the energy use per guest night, the data on the total number of hotel guests and nights were collected via individual interviews with hotel managers. While the data on the total number of guests were easy to obtain, the retrieval of figures on the total number of guest nights proved to be more difficult. Hotel 2 did not have this information at hand in an aggregate form; hence, in order to obtain the required number, some additional calculations which involved an in-depth analysis of hotel statistics were made upon request by a hotel manager.

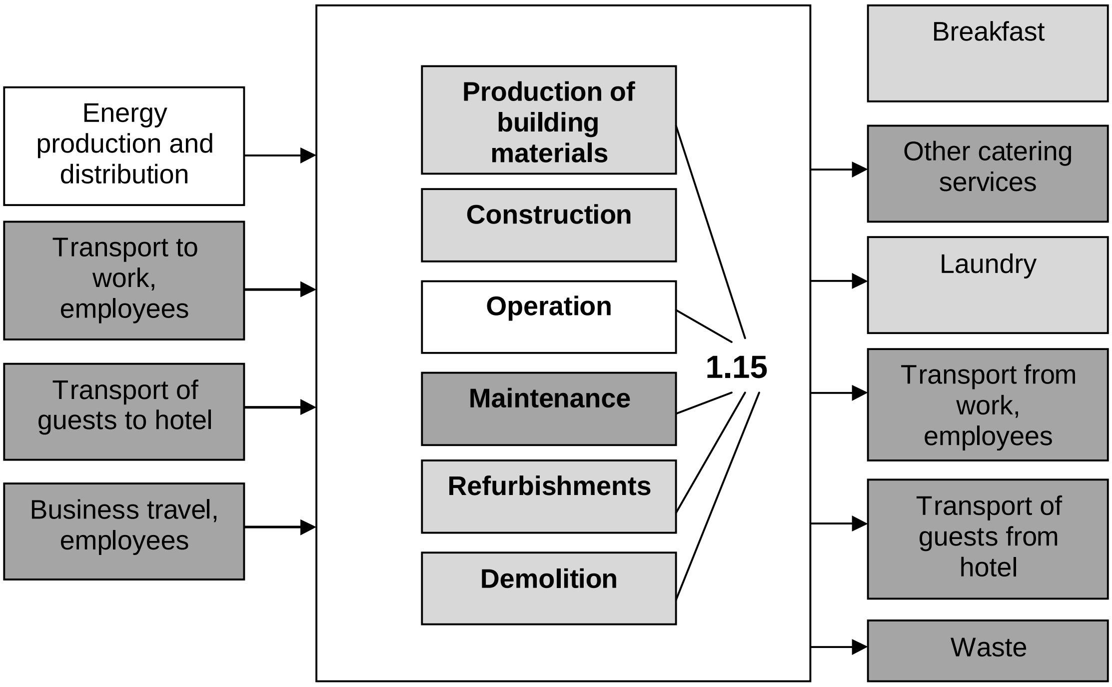


Figure 4.3. System boundaries for the case study hotels.

Source: modified from Ronning and Brekke (2009). White colour indicates processes/activities included in analysis and calculated directly; light grey colour indicates processes/activities included in analysis but estimated (not measured or calculated directly); dark grey colour indicates processes/activities excluded from analysis.

To obtain an estimate of the total number of guest nights in a hotel, an alternative method can be used. This method requires the values of the hotel's potential maximum annual occupancy and the figures on the hotel's actual annual guest occupancy on beds. If these are known, an *approximate* number of guest nights can be retrieved. This method was tested on the case study hotels. The analysis showed that it generated the estimates which were in agreement with the statistical data provided by hotel managers. Hence, it is argued that the applicability of this alternative method is justified when no precise value on the total number of guest nights in a hotel is directly available. However, it is acknowledged that actual hotel statistics is the most reliable data source for retrieval of this figure.

Importantly, the data on the *annual* energy use in the hotels were sufficient for this case study as it aimed to conduct a carbon footprint assessment of *an average* hotel guest. Disaggregation of these data is required if the GHG emissions need to be estimated for guests who stayed at the reviewed hotel within specific time periods. This can be the case, for example, when a hotel is contracted in summer by a single tour operator while it is open to other holidaymakers in other seasons. To assess the carbon footprint from the tour operator's clientele only, the data on the *monthly* energy use are required (see section 6.2.1.3 as an example). These monthly values can normally be easily retrieved from hotel energy bills.

To estimate the energy consumption per unit of GFA, the measure of the hotel area was required. It was provided by hotel managers who extracted the number from building plans of the hotels. While a manager from Hotel 1 had a building plan at hand, Hotel 2 did not have this information in-house and the GFA figure was requested from the head office in London.

Importantly, the GFA figure for the *whole* hotel was sufficient for this case study. Disaggregation of this figure is required if the energy intensity of *specific hotel's functional areas* is to be assessed. Such disaggregation enhances the quality of analysis as it helps identify the most energy-inefficient hotel zones where the primary energy-saving measures are necessary. In the case of the two hotels in Poole, UK, for example, it would be useful to have the data on energy usage per unit of GFA in different functional areas disaggregated. Hotel 1 is larger than Hotel 2 and the primary difference in size is due to the significant communal areas in Hotel 1. To better understand how the energy consumption per unit of GFA in the 'guest room' zone in Hotel 1 differs from the energy use in the 'guest room' zone in Hotel 2, the functional area-specific disaggregation of the energy data is required. However, it was not conducted in this case study as no functional area-specific energy meters were installed in the reviewed hotels.

The outsourced laundry and catering services were evaluated on the basis of actual hotels' laundry and restaurant bills. These provided an insight into the total number of breakfast food covers ordered from contracted restaurants and linen pieces sent to contracted laundries. These were supplemented with hotel managers' estimates as some information was missing. For example, Hotel 2 failed to provide a precise figure on the annual number of breakfast food covers ordered for its guests because breakfast is offered by the hotel on an optional basis. An estimate was produced by the hotel manager upon request.

The data on energy requirements for laundry and catering services were retrieved from the literature as empirical measurements were not feasible, also because both hotels refused to name their laundry sub-contractors for confidentiality reasons. Importantly, the energy use estimates for laundry services were based on weight and therefore required some additional calculations. The weight of laundry was obtained as follows: the data on the number of linen pieces annually sent to the laundry were collected from hotels' laundry bills. The linen pieces were then weighed to estimate how many pieces correspond to 1 kg of laundry. 1 kg of laundry was found to roughly correspond to 4 linen pieces. The total number of linen was then divided by 4, to obtain the total weight of laundry in the reviewed hotels per annum.

Last but not least, to conduct a comparative analysis of energy use practices in the case study hotels over tourist accommodation establishments elsewhere, and to better understand the determinant factors which affect the energy consumption in the reviewed hotels, general information on hotel buildings (for example, age, type of construction, type of wall insulation, type of windows, type and variety of energy-consuming services, type of energy carriers, type and frequency of refurbishment) and services provided by hotels is required. This information was collected via informal interviews with hotel managers accompanied by a guided tour throughout the hotel premises.

To summarise, the case study has outlined the basic data requirements for LCEA of a hotel. It has demonstrated that the primary data should be fairly easy to obtain although some hotels may have problems with providing high quality data due to the issues with data disaggregation and storage. This emphasises the necessity to establish strong links with the data providers, i.e. hotel managers. The willingness of hoteliers to cooperate on energy use analysis has been identified as a crucial factor for successful application of LCEA in the field of tourist accommodation. This is because some supplementary calculations may be required from hotel managers in addition to the data contained in hotel's energy bills. Another important finding of this case study is that the data requirements for LCEA in the tourist accommodation sector are similar to the data requirements imposed by the alternative methods for carbon footprint assessment in tourism, such as DEFRA.

4.5.4 Assessing the GHG emissions from the case study hotels

The LCEA case study of hotels in Poole, UK, has demonstrated that their energy performance per unit of GFA (206 and 220 kWh/m^2/annum) is fairly similar to the results of an energy audit conducted in four 3* and 4* hotels with catering services in the Mediterranean region (Dascalaki and Balaras 2004). Dascalaki and Balaras (2004) revealed the range of annual energy consumption between 170 and 270 kWh/m ^{2}. However, in comparison, Accor – Environment Guide (1998) suggests that the reviewed hotels are more energy efficient than Accor chain hotels. The total energy requirements of the Accor hotels, in a similar climate, are equal to 274-360 kWh/m ^{2}. Despite being dated, these values are nevertheless 25-75% higher than the EUI in the two Poole hotels. This may be because the case study hotels are relatively new and therefore have better insulation standards.

Further analysis of the EUI values indicates that the reviewed hotels are more energy-intense compared to hotels in New Zealand, Tunisia and Vietnam, have similar energy use levels with some hotels in Europe, Canada and Jamaica and are less energy-demanding than tourist accommodation establishments in Hong Kong, Turkey and USA (Table 4.2). The discrepancy in energy consumption figures between the reviewed hotels and other studies can be explained by differences in climatic conditions of the studied regions. It can also potentially be a result of continuous improvements in energy efficiencies as some of the studies reported in the literature sources are using data from the early and mid-1990s.

As for European tourist accommodation facilities in general, there is evidence, though somewhat obsolete, that their average total energy consumption ranges from 250 kWh/m^{2} per year (small hotels) to 450 kWh/m^{2} per year (larger hotels) (European Commission 1994 cited Dascalaki and Balaras 2004). This suggests that the case study hotels are more energy-efficient compared to the average tourist accommodation facilities in Europe.

When the energy use per ‘1 guest night’ is calculated, the analysis indicates that the reviewed hotels (11.2 and 15.2 kWh/guest night) show better performance than the 3* tourist accommodation establishments in Italy, where the values of about 28 kWh/guest night have been reported (Beccali *et al.* 2009). However, the hotels in the Italian study are bigger, located in milder climate and include energy consumed for in-house cooking and laundry - services not provided by the hotels under review. If the energy use for outsourced laundry and catering is added to the picture, the reviewed hotels demonstrate similar performance.

Table 4.2. Annual energy consumption patterns in hotels.

Source	Location	EUI (MJ/m^2/year)
Becken *et al.* (2001)	New Zealand	Motel = 250
		Bed & breakfast = 300
		Hotel = 571
		Backpacker = 617
Trung and Kumar (2005)	Vietnam	Resort = 280
		2* hotels = 365
		4* hotels = 510
		3* hotels = 515
EU (1994 cited Bohdanowicz *et al.* 2001a)	Southern Europe	460-615
Bohdanowicz *et al.* (2001b)	Sweden	590
Khemiri and Hassairi (2005)	Tunis (Tunisia)	615
Dascalaki and Balaras (2004)	Greece	625
Bohdanowicz (2006)	Sweden	720-1370
Gaglia *et al.* (2007)	Greece (average)	740
This case study	**Poole (UK)**	**742 (Hotel 1)** **792 (Hotel 2)**
Dascalaki and Balaras (2004)	Italy	775
Brunotte (1993 cited Becken *et al.* 2001)	Europe	860-1080
Marbek Resource Consultants and Policy Research International (1997 cited Becken *et al.* 2001)	Canada	900
Adelaar and Rath (1997)	Jamaica	900
Mortimer *et al.* (1999)	UK	900-1100
Rezachek *et al.* (2001)	Hawaii (USA)	930
Chow and Chan (1993 cited Deng and Burnett 2000)	Hong Kong	930
Bohdanowicz *et al.* (2004a)	Scandinavia	970 (average)
Santamouris *et al.* (1996)	Greece	985
Dascalaki and Balaras (2004)	France	1010
	Spain	1035
Perincioli (2006)	Switzerland	1117 (average)
EIA (2003 cited Perez-Lombard *et al.* 2008)	USA	1140
US EPA (2005)	USA	1150 (average)
Chan and Lam (2002b)	Hong Kong	1230
Rezachek *et al.* (2001)	Stockholm (Sweden)	1300
Perincioli (2006)	Switzerland	1300
Chan (2005); Lam and Chan (1994)	Hong Kong	1320 (average)
Onut and Soner (2006)	Turkey	1400
Energy Information Administration (1995 cited Deng 2003)	USA	1440
Priyadarsini *et al.* (2009)	Singapore	1540
Bloyd *et al.* (1999 cited Priyadarsini *et al.* 2009)	Singapore	1685
Karagiorgas *et al.* (2006)	Greece	1730
Deng (2003)	Hong Kong	1950
Deng and Burnett (2000, 2002)	Hong Kong	2030
Zmeureanu *et al.* (1994 cited Deng 2003)	Ottawa (Canada)	2480
Energy Efficiency Office, Department of the Environment, UK (1994 cited Deng 2003)	London (UK)	2570

The case study hotels are considerably less energy-intense than the tourist accommodation facilities in Australia where the values of 47-94 kWh/guest night have been reported (Earthcheck 2005 cited Lundie *et al.* 2007) and hotels of the Scandic chain (Bohdanowicz *et al.* 2004a; Scandic 2009), where an average energy consumption of 47 kWh/guest night in 2003 and 41 kWh/guest night in 2009 has been recorded. Again, the discrepancy in results can be attributed to the hotel size (the average floor area of Scandic hotels is about 10000 m^2), climatic conditions (Scandic hotels are located in Scandinavia and Central Europe), and the broader range of services provided. The benchmark of the Green Globe 21, an organisation that develops an international environmental management and certification system for the hotel sector, is 133 kWh/guest night (Bohdanowicz and Martinac 2007; Scandic 2009), which is far above the values reported for Scandic hotels and the case study hotels. This raise questions about credibility and currency of the Green Globe 21 certification programme as many tourist accommodation establishments are much more energy efficient than required by its criteria. Moreover, this suggests that tourism certification schemes need to be constantly updated to account for continuous improvements in hotel energy performance.

LCEA estimated the carbon footprint from the reviewed hotels as equal to 4.5 and 7.5 kg of CO_2-eq. per guest night (operational GHG emissions only, the carbon footprint from outsourced laundry and catering services is excluded). The contribution of the 'indirect' GHG emissions related to the energy-producing capital goods and infrastructure was found to be negligible, equating to approximately 2.5% of the total. This finding is in broad agreement with Frischknecht *et al.* (2007a) who argue that the share of the capital goods and infrastructure for electricity use and heating with natural gas varies from 1 to 7%.

The carbon footprint from the case study hotels grows to 8.3 and 11.7 kg of CO_2-eq. per guest night when the energy embodied in the hotel building and arising from the outsourced catering and laundry services is added to the picture. The analysis further shows that the outsourced catering and laundry services have a significant contribution of up to 30-40% to the overall energy consumption and consequent GHG emissions from tourist accommodation facilities. This finding is in line with the literature which reports that the GHG emissions from the tourism supply chain can be large (see 2.4.7 for a detailed discussion). This is also in agreement with some studies which have estimated the carbon contribution of the laundry and catering services to the total carbon footprint from hotels as significant (see, for example, Ali *et al.* 2008; Greenhotelier 2005a cited Sloan *et al.* 2009).

Last but not least, the case study shows that the carbon footprint from the reviewed hotels is significantly lower than the figures reported for tourist accommodation facilities in previous research (Table 4.3). One potential reason is the obsolescence of the literature data due to the improved energy performance in hotels. The difference in the occupancy rates and size of hotels is another explanation.

4.5.5 Extending the testing grounds of LCEA: a case study of a weekend holiday trip

The case study of two hotels in Poole, UK, has demonstrated the applicability of LCEA in the tourist accommodation sector. It has also shown that the data requirements for LCEA do not exceed the data needs for alternative methods for carbon impact appraisal in tourism. To provide empirical evidence to the viability of this method for carbon footprint assessment of other elements of holiday travel and to further hone the LCEA assessment skills, a case study on the carbon impact appraisal of a short holiday trip has been performed. This case study aimed to estimate the GHG emissions of a weekend journey from London to Poole, UK, which is a popular holiday itinerary with the residents of London, especially in summer. The results of the case study were reported in a journal article (Filimonau *et al.* 2011a, see Appendix 2).

The following simplified scenario has been developed for this case study: tourists start the journey on Saturday morning in London and travel to Poole by coach. In Poole they stay overnight in a 3-star hotel and return home on Sunday evening. The analysis accounts only for those GHG emissions associated with travel by coach and the hotel stay. The carbon impacts arising from tourist activities (for example, shopping, dining, and excursions) and other tourist transport (for instance, travel from home to coach station in London and travel from coach station to the hotel in Poole) are excluded. These elements of holiday travel will be holistically assessed in the context of the holiday package (see Chapter 5). The results of the LCEA analysis for one of the hotels in Poole were used for carbon footprint assessment of hotel stay in this case study. The carbon impacts associated with '1 passenger km driven by coach' and '1 guest night hotel stay' have been used to define the functional units of analysis.

Table 4.3. GHG emissions from tourist accommodation establishments in comparison to the case study hotels in Poole, UK.

Source / Accommodation type	**Geographical scope**	***Hotel***	***Motel***	***Campsite***	***BB***	***Pension (private home)***	***Backpacker (hostel)***
		kg CO_2 per 1 guest night (unless stated otherwise)					
Cleaner Climate (2010), *calculations on a 'per room night' basis*	International	47-84	-	-	-	-	-
	UK	48	-	-	-	-	-
CarbonNeutral Company (2008 cited Chenoweth 2009); *calculations on a 'per room night' basis*, CO_2-eq.; no explanation on how the data have been derived	UK	34.32	-	-	-	-	-
	International	33.87	-	-	-	-	-
DEFRA (2009 cited Carbon Neutral Company 2010) and CIBSE (2004 cited Carbon Neutral Company 2010); *calculations on a 'per room night' basis,* CO_2-eq.; no explanation on how the data have been derived	UK	33.45	-	-	-	-	-
	International	31.93	-	-	-	-	-
Carbon Fund (2010), *calculations on a 'per room night' basis*	USA	33.38 (upscale hotel); 29.53 (average hotel)	-	-	-	-	-
MyClimate (2010)	Switzerland	26 (5*); 14 (4*); 8 (3*)	-	-	-	-	6
Becken *et al.* (2001); values are given in MJ but converted using a global average of 158.4 g of CO_2 per 1 MJ for 1990, derived from Schafer and Victor (1999); an approach adapted from Gössling *et al.* (2005)	New Zealand	24.6	-	4	17.5	-	6.2
Sustainable Tourism Cooperative Research Centre - ST CRC (ST CRC 2010)	-	24	8	1.4	5	9	3
Chan and Lam (2002b); electricity consumption only; *calculations on a 'per room night' basis, single room occupancy is assumed*	Hong Kong	23.4 (5*); 18.7 (4*); 14 (3*), public and service areas exclusive; 37.4 (5*); 32.7 (4*); 28 (3*), public and service areas inclusive	-	-	-	-	-
Gössling (2002)	-	20.6	-	7.9	-	4	-
Sustainable Travel International – STI (STI 2009), *calculations on a 'per room night' basis*	North America	15.3	-	-	-	-	-
Landcare Research (2010)	New Zealand	7.97	2.56	1.36	4.14	0.24	2.12
STI (2009), *calculations on a 'per room night' basis*	Europe	3.9	-	-	-	-	-
Offsetters (2010), *calculations on a 'per room night' basis,* CO_2*-eq.*	Vancouver, Canada	2; lower number is due to the use of hydro electricity	-	-	-	-	-
This study estimates	**UK**	**Operational GHG emissions only = 4.5 (Hotel 2) and 7.5 (Hotel 1); Operational + embodied + outsourced laundry and catering services GHG emissions = 8.25 (Hotel 2) and 11.65 (Hotel 1)**					

The case study shows that LCEA can be used for holistic estimates of the GHG emissions from tourist transport and accommodation. The method provides a useful insight into the 'indirect' energy use and carbon footprint. The LCEA analysis demonstrates, for example, that the contribution of the 'indirect' GHG emissions for coach travel accounts for 13% of its total carbon footprint (Table 4.4; see section Case study in Filimonau *et al.* 2011a, Appendix 2). This number is in relatively good agreement with Frischknecht *et al.* (2007a) who found that the share of the 'indirect' energy and carbon requirements for road passenger transport may equate to 15-19%. When this 'indirect' carbon contribution is supplemented with the 'indirect' GHG emissions from the outsourced hotel services and the carbon footprint embodied in the energy producing capital goods and infrastructure, the final 'indirect' share in the total GHG emissions from the reviewed holiday trip accounts for 22%.

Table 4.4. GHG emissions from a weekend holiday trip from London to Poole (kg CO_2-eq. or kg CO_2 per 1 tourist), as estimated by different methods.

Holiday trip element / Assessment method	**DEFRA (2009)**	**Method from Gössling *et al.* (2005)**	**LCA/LCEA**
Coach travel from London Victoria to Poole Dolphin Centre, *180 km*	5.51	3.91	9.34 (where 1.2 are 'indirect' emissions)
1 overnight stay in Poole	6.83	8.7	7.51
Electricity use, *40 MJ / night*	*6.07*	*6.34*	*6.45*
Hot water production, *14.9 MJ / night*	*0.76*	*2.36*	*1.06*
Coach travel from Poole Dolphin Centre to London Victoria, *180 km*	5.51	3.91	9.34 (where 1.2 are 'indirect' emissions)
Total	**17.85**	**16.52**	**26.19**

The case study has also demonstrated that there is a necessity to test the applicability of LCEA for carbon impact appraisal of another important element of holiday travel, i.e. tourist activities. The case study of a holiday package should help rectify this gap. Assessing the direct and 'indirect' carbon footprints from specific composite tourism products is useful as it establishes the relative carbon significance of their specific elements, thus highlighting the areas for carbon mitigation measures.

Last but not least, the case study indicates that, under short-haul travel settings, the accommodation element of holiday travel contributes significant quantities of GHG emissions to the total carbon footprint from the reviewed holiday journey (Table 4.4). These are responsible for about 30%, if outsourced services are excluded, and for almost 40%, if outsourced services are taken into account. This suggests that tourist accommodation should not be ignored when estimating the GHG emissions from short-haul holiday trips. Moreover, measures need to be developed for cutting the energy use and carbon footprint from hotels as this is the area where a large reduction potential exists. The non-transport element of the GHG emissions of short-haul holidays becomes even larger if the carbon impacts from other destination-based tourism products and services (for example, excursions, dining and shopping) are added to the picture.

4.6 LCA VERSUS ALTERNATIVE ENVIRONMENTAL ASSESSMENT TECHNIQUES

A comparative quantitative analysis of existing methodologies for environmental assessment in tourism has never been conducted. No studies were identified in the literature which would critically evaluate the performance of alternative assessment tools when applied for analysis of a single tourism product with given parameters.

The case study of a holiday trip from London to Poole performed a simplified comparative analysis of LCEA against alternative methods for carbon footprint assessment in tourism (Table 4.4). The results demonstrate significant discrepancies in estimates, i.e. in the range of circa 30-40% (see section Case study in Filimonau *et al.* 2011a, Appendix 2 for more details), thus calling for an in-depth analysis of potential reasons for their occurrence. Concurrently, the use of a single method for appraisal of environmental impacts may question the credibility of results (Lettenmeier *et al.* 2008); therefore the comparative and/or supplementary application of alternative assessment tools may be necessary to double-check the assessment outcome (Raggi *et al.* 2008).

The conceptual difference of LCEA from existing methods for appraisal of environmental impacts from tourism calls for a detailed comparative analysis of all techniques. The comparison should help better understand the reasons and the magnitude of potential discrepancies between the assessment outcomes generated by different methods. This in turn may help identify the best appraisal approach, or combination of approaches, for the most accurate and holistic appraisal of carbon impacts from tourism products and services.

4.7 SUMMARY

This chapter has demonstrated the potential of LCA for holistic appraisal of environmental impacts from products and services throughout the critical evaluation of its assessment framework and major analytical features. Despite the clear advantages of the technique, the review of existing appraisal studies on environmental impacts from tourism products, services and activities has shown the limited evidence of application of LCA in the tourism domain. The primary merit of LCA is in its ability to provide estimates of the 'indirect' environmental burdens. Concurrently, the 'indirect' carbon footprint from tourism is the area where more research is required. Hence, this chapter concludes that there is a necessity for broader application of the LCA methodology for appraisal of carbon impacts from tourism products and services. The application of LCA will help identify the contribution of the 'indirect' GHG emissions to the total carbon footprint from tourism. It should also provide valuable insights into how this 'indirect' share affects the relative carbon intensity of different elements of holiday travel, such as transportation, accommodation and activities. Moreover, given that no in-depth research of composite tourism products, such as holiday packages, has been held, this chapter calls for utilisation of the LCA methodology for holistic carbon impact appraisal of a holiday package tour.

The chapter has shown that the application of a full-scale LCA for carbon footprint appraisal of tourism is impractical. Its derivative, the LCEA technique, which focuses on energy consumption and handles GHG emissions as the only measure of environmental impact from a product or service is a better alternative. The analytical potential of LCEA has been demonstrated by conducting the case study on two hotels in Poole, UK, and extending this to estimate the carbon footprint for a short holiday trip.

The results of the hotel case study have indicated that the data requirements for LCEA in the tourist accommodation and transportation sector are similar to the data needs for alternative methods for carbon impact assessment. They have further shown that the largest amount of GHG emissions is produced by hotel operations while the contribution of the 'indirect' carbon footprint embodied in hotel building and equipment may equate to about 15% of the total. As it is not possible to retrieve a more precise figure from the literature due to the significant variance in estimates of the 'indirect' carbon impacts from the building life cycle, it is argued that this number should be employed for a sensitivity analysis, to test how the overall carbon intensity of the hotel stay changes, should the embodied GHG emissions be added to the picture. The case study has also found that maintenance and waste disposal are the 'grey' areas in the research on environmental impacts from hotels. These stages of the hotel life cycle may potentially contribute significant quantities of the 'indirect' GHG emissions; hence, they need to be considered in LCEA of tourist accommodation, subject to data availability. Importantly, the carbon impact from the supply chain of hotels, i.e. outsourced laundry and catering services, has been estimated by LCEA as significant.

The case study on a holiday trip has demonstrated the importance of the ‘indirect’ GHG emissions from coach travel. Since only a single transport mode was considered in this case study, there is a necessity to conduct LCEA for other transportation means to establish some representative values of their ‘indirect’ carbon requirements.

The case study has also shown that, in the reviewed short-haul travel, the relative carbon contribution of the non-transit element of holiday travel is significant. This finding clashes against the traditional perception of the relative magnitude of the GHG emissions from holidays albeit it is acknowledged that coach is one of the most carbon-efficient forms of motorised travel.

To further test the applicability of LCEA in tourism, there is a need to further adapt its general methodology to specific requirements of tourism research, cover a range of popular tourism products and services, and develop a number of case studies on different levels of tourism industries. The results of LCEA analysis need to be compared against the outcome of existing carbon impact appraisal tools to find a reliable evaluation approach, or combination of approaches, to produce the most accurate and holistic estimates of carbon impacts from tourism products. The next chapter introduces the case study of a standard holiday package in the British tourism market which has been selected to address some of the above knowledge gaps.

CHAPTER 5. LCA (LCEA) OF A COMPOSITE TOURISM PRODUCT: PRODUCT SELECTION AND THE ASSESSMENT FRAMEWORK

5.1 INTRODUCTION

The carbon footprint from the holiday package tour has never been holistically assessed (Peng and Guihua 2007). The primary reason may relate to its composite structure which creates the impression that appraising the full magnitude of the carbon impacts from the holiday package is a difficult task to fulfill. The requirement to operate a reliable assessment technique capable of estimating the carbon footprints from *all* elements of holiday travel at the same time is another explanation. Nevertheless, holiday package tours have a large market share in many tourism markets. This may result in significant quantities of associated GHG emissions. Hence, there is a clear need for more in-depth research on the holistic and accurate carbon impact assessment of these popular tourism products, and the relative carbon footprint share of each of their elements.

Chapter 4 has demonstrated the potential of LCA (LCEA) as a promising tool for carbon impact appraisal of such fundamental elements of holiday travel as tourist transport and accommodation. There is a need to further test the applicability of LCA (LCEA) on a broader range of tourism products and services, including tourist activities. This will provide further empirical evidence as to whether this method is a viable technique for making holistic estimates of GHG emissions from tourism. A new insight into the life cycle carbon intensity of popular tourism products will also be gained. A further important research aim is to compare LCA (LCEA) against existing alternatives for carbon impact appraisal in tourism, to better understand the merits and limitations of each.

This chapter introduces a case study which aims to apply LCA (LCEA) to a standard holiday package in the British tourism market. It outlines the criteria used for selection of the package tour, establishes the system boundaries and discusses the functional unit for analysis. The model for basic data collection is introduced and the major data sources and data mining approaches are critically reviewed. The main approaches to data analysis are outlined.

5.2 SELECTING THE HOLIDAY PACKAGE FOR ANALYSIS

The holiday package tour required for analysis has to fulfill a number of criteria. The primary requirement is that it must be based on a short-haul tourist destination. The need to perform more accurate and holistic carbon footprint assessment of short-haul holidays in order to critically evaluate the relative carbon significance of their specific elements has been identified in the literature review (see 2.4.1 for discussion).

5.2.1 'Short haul' travel distance as a primary criterion for selection

There is no clear categorisation of the 'short-haul' travel distance in the literature. The definitions vary depending on transport mode and geography. With regard to air travel, DEFRA (2009) refers to short-haul international flights as to 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 flights adopted in North America suggests the travel distance of around 500 km. For example, WRI classifies the short-haul flights as those of less than 452 km in length (Clean Air Conservancy 2010). These figures largely correspond to the definition of regional (or domestic) flights when applied in the European context (DEFRA 2010a). 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 2010a).

For this case study, the definition adopted by EEA (EEA 2007) and Peeters and Schouten (2006) has been employed. It argues for short-haul flights to be within the range of up to 1850-2000 km. These figures are in between the short-haul distance extremes identified in the literature, i.e. 452 and 3700 km.

It is further argued that the most suitable holiday destinations for analysis are those located within the travel distance of 1000-2000 km from the UK. The so-called 'extremely short-haul' flights, i.e. <800-1000 km (Matheys *et al.* 2008) represent a small share of the total air travel market. Nevertheless, they make a profound carbon impact per 'passenger km' due to the substantial energy requirements and GHG emissions associated with take-off and landing (Egli 1996 cited Gössling 2000; Jardine 2005). For example, the amount of fuel consumed by Airbus 320 series aircraft for take-off and landing may equal the amount of fuel burnt to fly about 800 km at a constant cruising altitude (Koroneos *et al.* 2005). For Boeing 737 series aircraft, the fuel consumption for take-off and landing can be around 25% of all fuel burnt during the flights within the range of 900 km (Jardine 2005). In addition, these ‘extremely short-haul’ flights are often serviced by the older and less fuel efficient aircraft (Chapman 2007). This demonstrates that the short-haul travel distances within the range of 1000-2000 km are more carbon efficient when estimates are made on a ‘per passenger km’ basis. This argument finds confirmation in the literature (Jardine 2005; Koroneos *et al.* 2005). Hence, the short-haul holiday packages based on the destinations located within 1000-2000 km from the UK are deemed to be the most valid objects for analysis.

5.2.2 Determining a suitable holiday package

The case study aimed to conduct a LCA (LCEA) analysis for a standard short-haul holiday package available in the British tourism market and fulfilling the criterion of the short-haul destination discussed in 5.2.1. To select a suitable package, contacts with the largest provider of package holidays in the UK were established.

‘Touristik Union International (TUI) UK and Ireland Public Limited Company (PLC)’ (referred to as the TUI Travel thereafter), operating under the trading names ‘First Choice’ and ‘Thomson’, is the UK’s leading leisure travel company. It offers a variety of holidays and charter flights from the UK to the most popular tourist destinations worldwide (Fist Choice 2010; Thomson Holidays 2010). The company specialises in tailor-made holiday packages, a significant share of which is represented by the ‘all-inclusive’ tour.

The representatives of TUI Travel were first contacted in December 2008 to discuss their willingness to help with this project. The company understood the project requirements and agreed to partake. Initially, four tourist destinations were proposed by TUI Travel for analysis: the Algarve (Portugal), Lake Garda (Italy), Amsterdam (the Netherlands) and Crete (Greece) (Figure 5.1). The company expressed the readiness to disclose the data on tourist statistics for these destinations and agreed to help establish contacts with the management of a suitable tourist accommodation facility. After a critical analysis, the destinations Lake Garda, Amsterdam and Crete were rejected. Unlike other proposed tourist destinations, Amsterdam is a typical ‘city break’ tourist destination which is usually not offered as ‘package’ holiday. Moreover, it is located very close to London; the one-way travel distance is 366 km (Air Routing International 2011), i.e. it is an ‘extremely short-haul’ destination which is not a focus here (see 5.2.1). Lake Garda is 900 km from London [8] (Distance Calculator 2010) which is marginally below the 1000 km cut-off point while the Algarve (Portugal) is middle of the 1000-2000 km zone (distance from London is 1687 km) (Air Routing International 2011). Crete is 2683 km from London (Air Routing International 2011), which is classified as a medium-haul tourist destination, and is beyond the scope of this study. Thus, the Algarve (Portugal) was identified as the most suitable holiday destination for analysis.

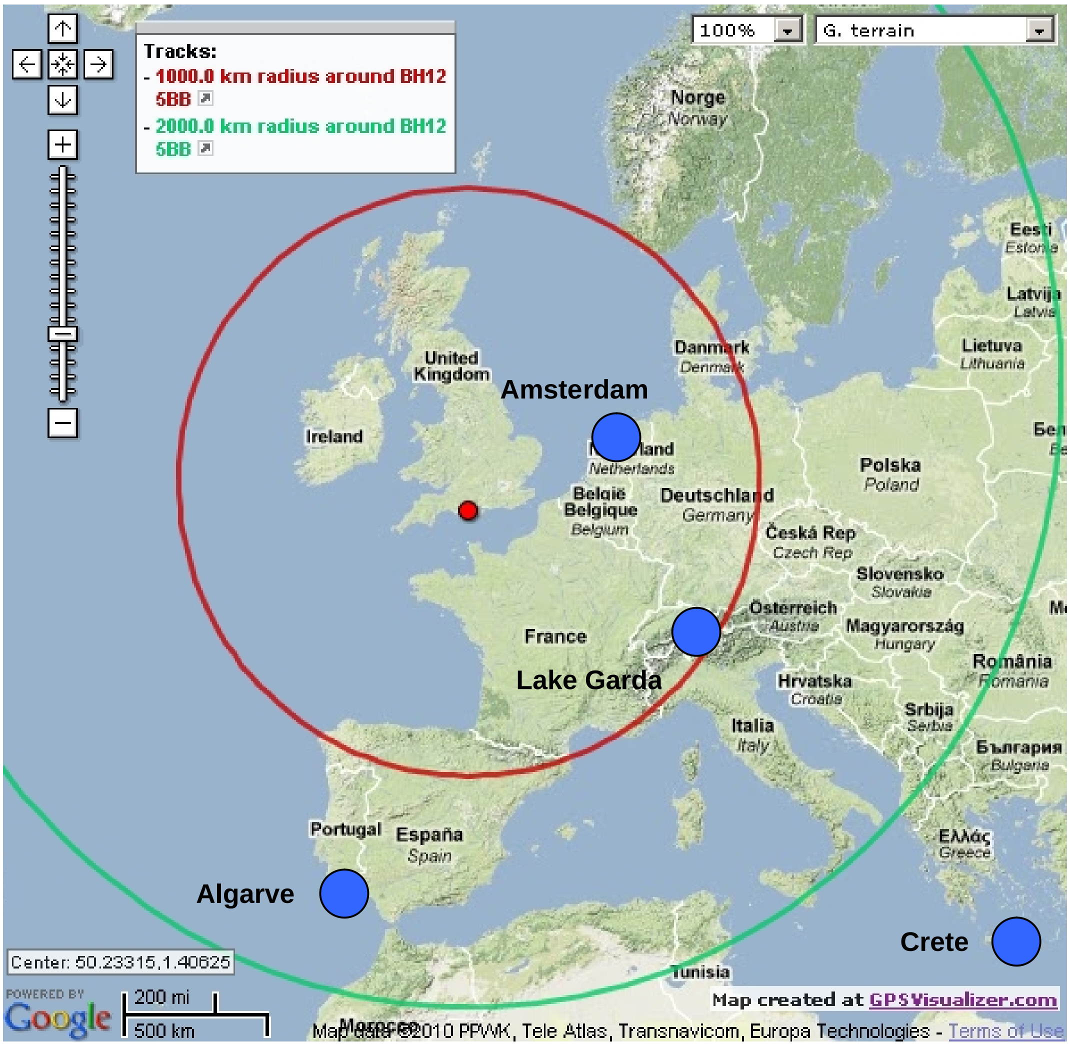


Figure 5.1. The map of suitable short-haul holiday destinations within the range of 1000-2000 km from the UK.

Source: Author adapted from Google Maps (2011). Bournemouth has been taken as the centre for distance calculation. Map created by Global Positioning System - GPS Visualizer (2010).

[8] The distance between London Gatwick and Milan Malpensa, the closest international airport to Lake Garda.

Portugal with about 2 millions of visits in 2010 is the sixth most popular destination with Britons in Europe (Table 5.1, Office for National Statistics 2010). Three out of five more popular tourist destinations (France, Ireland and Germany) are within the range of less than 1000 km from the UK. This means that they are beyond the scope of this study. The remaining two more popular destinations (Spain and Italy) are between 1000 and 2000 km. Furthermore, it is argued that there are more similarities between Portugal and Spain, the market leader destination, than between Italy and Spain. This is due to similar geographical conditions, economic development and social lifestyles. This serves as another argument in support of the selection of Portugal as an object for a LCA (LCEA) case study.

Table 5.1. Top-10 European destinations for visits by Britons abroad: by country of visit; 2010.

Source: Office for National Statistics (2010).

№	**Country**	**Number of visits, million**	**Average distance range from the UK, km**	**% of visits (of the total to the Top-10 destinations)**
1	Spain	10534	1000-2000	30
2	France	9041	< 1000	26
3	Ireland	2904	< 1000	8
4	Italy	2251	1000-2000	6
5	Germany	2080	< 1000	6
6	***Portugal***	***1905***	***1000-2000***	***5***
7	Turkey	1802	> 2000	5
8	The Netherlands	1751	< 1000	5
9	Greece	1676	> 2000	5
10	Belgium	1373	< 1000	4

TUI Travel operates a number of resorts under the destination brand ‘Algarve’. The resort selected for a LCA (LCEA) analysis is the ‘Holiday Village (HV) Algarve’ in Albufeira, which is a popular holiday destination with Britons, situated in the central part of the Algarve region (First Choice 2009b). This specific resort was chosen due to a number of reasons. First, the owners of this business were described by TUI Travel as ‘cooperative’ (James Whittingham, Group Environment Manager, TUI Travel PLC, personal communication, 15 January 2009). This is in contrast to other TUI Travel contracted hoteliers in the region who were often referred to as ‘sensitive and very protective of their businesses’. The discussion with TUI Travel implied that HV Algarve would be more likely to provide the data on energy consumption necessary for a LCA (LCEA) analysis. Second, HV Algarve was chosen as in summer season it is open exclusively to the TUI Travel clients from the UK while other holiday establishments in the Algarve operating under the brand ‘TUI Travel’ also serve the TUI Travel clientele from other source markets like, for example, Germany, Scandinavia and Switzerland (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). This allowed easier access to data on tourist numbers from the UK. Third, HV Algarve is offered to Britons as an 'all-inclusive' holiday package. Although 'all-inclusive' holiday package tours have been recognised as the most suitable objects for environmental assessment (Hunter 2002), there are no holistic studies in this domain (Becken *et al.* 2003a). This case study aims to plug this research gap.

The average duration of package holidays operated by TUI Travel in HV Algarve is 9.8 nights (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). This is longer than the average length of stay of the 'all-inclusive' holiday tours undertaken by Britons in 2008 worldwide (9.0 nights) and in EU-27 countries (8.1 nights) (Office for National Statistics 2009). This notwithstanding, this figure is very close to the average duration of holidays undertaken by British tourists in Portugal (regardless of the visit type) which in 2008 was 9.6 nights (Office for National Statistics 2009). This factor was also considered when making the final selection of the holiday package for a LCA (LCEA) analysis.

The HV Algarve resort contains the 4* hotel complex Alto da Colina Aparthotel. The contact details of the hotel management were provided by TUI Travel. HV Algarve was contacted in June 2010 to discuss their willingness to partake in the project. The agreement was obtained upon condition that the data collection for LCA (LCEA) takes place out of, or in the fall of, the high season. Hence, the field phase of the study was conducted in late August 2010. The data analysis was performed in autumn-winter 2010-11.

5.3 GOAL AND SCOPE DEFINITION FOR LCA (LCEA) OF THE HOLIDAY PACKAGE IN THE ALGARVE

The goal of this case study is to conduct a holistic carbon impact appraisal of the standard holiday package in the UK's tourism market. It aims to estimate the total GHG emissions of the holiday package and the GHG emissions attributable to its different elements and to better understand their relative carbon intensity thus identifying the primary contributors to the total carbon footprint. The magnitudes of the 'indirect' GHG emissions embodied in the non-use phases of the life cycle of different holiday package elements, and arising from the capital goods and infrastructure, are determined.

5.3.1 Bottom-up versus top-down analytical approach

To achieve the goal of this case study, the process-based LCA is used for analysis. This is because this category of LCA has been specifically designed to carry out environmental appraisals on a product and service level and since more accurate LCA methodologies are yet to be developed (see 4.2.2).

This LCA (LCEA) case study is based on the bottom-up (or component-based) analytical approach. It first evaluates the individual carbon impacts from different elements of the holiday package or travel choices. Further summation of these impacts produces the estimate of the total carbon footprint from the entire holiday package tour. Such a component-based, bottom-up model of carbon impact appraisal is more suitable for smaller contexts, i.e. for the product scale analysis (Ronning and Brekke 2009; Simmons *et al.* 2000), particularly when the necessity to account for the lifecycle environmental impacts arises (Hunter *et al.* 2006). It is argued that it can link local consumption and associated environmental burdens to global impacts more straightforwardly (Collins and Flynn 2005). This notwithstanding, the literature reports a limited number of applications of the bottom-up approach for analysis of energy consumption and consequent GHG emissions from tourism (Kelly and Williams 2007).

The opposite of the bottom-up method is the compound-based or top-down approach which has been the basis of the majority of existing environmental assessments in tourism (Peng and Guihua 2007). This approach first evaluates the environmental impacts from the entire product system. The analysis can then be narrowed down to determine the contribution of each element of the system under review. The top-down method is primarily utilized to estimate the carbon impacts at larger scales like, for example, at the national level (von Rozycki *et al.* 2003; Simmons *et al.* 2000). It has also been applied to the environmental assessment of impacts from the specific industrial sectors and larger product groups (Ronning and Brekke 2009). The top-down approach is often too crude (Hunter 2002) and may therefore encounter issues when a detailed breakdown of the element-specific impacts is required (Collins and Flynn 2005; Collins *et al.* 2007). In addition, it is less flexible (von Rozycki *et al.* 2003) and provides fewer opportunities for scenario and sensitivity analyses (Simmons *et al.* 2000). Since the focus of this case study is on a smaller scale, i.e. on the level of specific holiday packages, the bottom-up approach is selected.

5.3.2 System boundary

The system boundary for the holiday package in the Algarve follows the 'door-to-door' concept suggested by Chambers (2004) which largely represents a traditional modular approach broadly employed in process-based LCA studies (see Jungbluth *et al.* (2000) for details). The reviewed holiday package system includes all process units (product stages or holiday travel elements) starting with the departure of tourists from home to their return (Figure 5.2). These are transport to/from airport in the country of origin, transport to/from the destination, transport to/from airport at the destination, accommodation and tourist activities at the destination. Importantly, although travel to/from airport in the origin country is not a traditional element of a holiday package as it is usually organised by tourists independently, it has been included into the scope of LCA (LCEA) analysis in this case study as it is deemed to be an indispensable element of any holiday travel experience. Another reason for inclusion is to better understand the relative carbon significance of travel to/from airport in the origin country compared to the 'traditional' holiday travel elements of the reviewed holiday package.

The preparatory elements of holiday travel (for example, booking of holidays, shopping for holiday apparel and money exchange) and the post-return activities (for instance, photo printing services, sharing the holiday experience with friends and relatives in cafes and restaurants) and associated carbon footprints are disregarded in this case study. This is due to the constraints in data retrieval and because of the low carbon contribution envisaged from these elements.

To estimate the carbon footprint from the holiday package in the Algarve, separate carbon impact inventories are constructed for each process unit of the holiday package. The inventories include both the direct and 'indirect' lifecycle GHG emissions (Figure 5.2). This enables a comparative analysis of the contribution that different process units make to the total carbon impact of the holiday package. The overall carbon footprint is estimated by totaling the carbon footprints from the process units.

When appraising the 'indirect' GHG emissions from the holiday package in the Algarve, a system boundary also has to be set up. This is because the magnitude of the 'indirect' carbon impacts can be infinite, should all orders of tourism suppliers and all dimensions of the 'indirect' GHG emissions be included in the analysis. Following the LCEA guidelines, the system boundary established in this case study aimed to account for the *most significant* contributors to the total GHG emissions from the holiday package, as identified from the literature.

Generic	*Origin country element*	*Transit element*	*Destination country element*				*Transit element*	*Origin country element*
	Transport element			Non-transport element	Mixed element	Transport element		
	Travel to airport	**Flying**	**Travel from airport**	**Accommodation**	**Activities**	**Travel to airport**	**Flying**	**Travel from airport**
Example	Bournemouth – London Gatwick, car	London Gatwick – Faro Airport	Faro Airport – HV Algarve, coach	HV Algarve, 10 days	- 5 beach visits, bus; - 1 aqua park visit, bus - 2 eating out, taxi	HV Algarve - Faro Airport coach	Faro Airport – London Gatwick	London Gatwick - Bournemouth, car

GHG emissions included in the system boundary for analysis

Direct	Fuel combustion	Fuel combustion	Fuel combustion	Energy consumption (electricity and LPG)	*Motorised:* Fuel combustion *Non-motorised:* Energy consumption	Fuel combustion	Fuel combustion	Fuel combustion
'indirect'	- Vehicle life cycle - Road infrastructure life cycle - Fuel chain life cycle	- Aircraft life cycle - Airport infrastructure life cycle - Fuel chain life cycle	- Coach life cycle - Road infrastructure life cycle - Fuel chain life cycle	- Fuel chain life cycle - Hotel building life cycle* **used for a sensitivity analysis only*	*Motorised:* - Vehicle life cycle; - Road infrastructure life cycle; - Fuel chain life cycle *Non-motorised:* -Fuel chain life cycle	- Coach life cycle - Road infrastructure life cycle - Fuel chain life cycle	- Aircraft life cycle - Airport infrastructure life cycle - Fuel chain life cycle	- Vehicle life cycle - Road infrastructure life cycle - Fuel chain life cycle

Figure 5.2. System boundary for LCA (LCEA) of the holiday package in the Algarve.

NB: the composite structure of some holiday packages may differ from the one considered in this case study. Source: Author.

The following categories of the 'indirect' carbon footprint from tourist transport are included in analysis: vehicle life cycle, transport infrastructure life cycle and fuel chain life cycle (Figure 5.2). This implies that all known categories of the 'indirect' carbon impacts from tourist transport will be holistically appraised.

Tourist accommodation is an element of the holiday package where establishing a feasible system boundary for analysis of the 'indirect' GHG emissions has proven to be less straightforward. In addition to the non-operational (embodied) carbon footprint from the hotel building, furniture and equipment, the necessity to account for the carbon impacts from guest transportation, staff commuting, business travel and other non-accommodation related tourist activities attributable to the operation of hotels (for example, car rental services) can cause problems. The literature review suggests that these elements alongside operational waste generation and routine building maintenance are usually excluded from assessment due to the poor data quality (see, for instance, Ronning and Brekke 2009) although the need to address this issue is acknowledged (De Camillis *et al.* 2010). In the case study of the holiday package in the Algarve, the estimate of the GHG emissions embodied in the hotel building, which are assumed to be 15% of the building's operational carbon footprint, will be used for a sensitivity analysis. This is because no direct measurements are available while this estimate of the embodied carbon footprint has been produced by compiling a range of (averaged) figures reported in the literature (see 4.5.1). All other services, which are not directly related to the hotel operations (including waste generation by hotel guests), will be excluded from carbon footprint appraisal. This is because quality data are not available for their holistic analysis. As a result, the inclusion of the carbon impacts arising from these activities is optional in DEFRA, ISO and the GHG Protocol carbon reporting guidelines (see Chapter 3). All this implies that the assessment of the 'indirect' carbon impacts from tourist accommodation conducted in this case study cannot be considered truly holistic as it excludes a range of carbon burdens imposed by the hotel suppliers.

Similar limitation needs to be acknowledged when appraising the 'indirect' GHG emissions from tourist activities. The 'indirect' carbon footprint from the motorised tourist activities is comprehensively assessed as the analysis includes the carbon impacts embodied in vehicle life cycle, road infrastructure life cycle and fuel chain life cycle. However, for non-motorised tourist activities only the 'indirect' GHG emissions related to the fuel chain life cycle are accounted for. The carbon footprint embodied in the capital infrastructure (for example, in the buildings of an aqua park or cooking equipment for food preparation in restaurants) is excluded as the data to holistically evaluate the carbon contribution of these inputs are unavailable.

5.3.3 Functional unit

The generic functional unit for this case study can be defined as the 'holiday package with certain duration of stay and structure'. However, the holiday package is a composite product which consists of a number of different elements associated with transport, accommodation and activities (Budeanu 2007). This suggests that assignment of a single functional unit for a LCA (LCEA) analysis of the holiday package is not feasible. Hence, a separate functional unit is allocated to each element of the holiday package under review.

The GHG emissions will be estimated on the basis of '1 passenger km' driven or flown (for all elements of the holiday package related to tourist transport), '1 guest night' stayed (for all elements of the holiday package related to tourist accommodation) and '1 tourist activity per tourist" undertaken (for all elements of the holiday package related to tourist activities). Moreover, as tourist activities often involve a transport element, such as coach excursion tours, car hire or a taxi to the restaurant, the appropriate supplementary, transport-related functional units will also be applied for their analysis. For example, a 'visit to the aqua park' tourist activity will be assessed on the basis of two functional units. The primary functional unit '1 tourist activity per tourist' will be employed to estimate the GHG emissions from visiting the aqua park while the supplementary functional unit '1 passenger km' will be used to characterize the carbon footprint from transport to/from the aqua park. Likewise, '1 tourist activity per tourist' is employed to assess visits to the restaurant while '1 passenger km' is necessary to appraise the carbon impacts from transportation to/from the restaurant.

Although the selection of such 'individual tourist-oriented' functional units can be criticized due to a small number of tourists surveyed being potentially under-representative of the large number of tourists annually going on holidays, it is argued that this approach is feasible since it helps better understand the individual contribution of holidaymakers to the global carbon footprint. Furthermore, these units are more useful for researchers and policy-makers as they help evaluate the progress of individual tourism businesses towards the goal of sustainability. This is also because many tourism operators have set their GHG emission mitigation commitments and targets in analogous units. The European airline industry, for example, aims to achieve reductions in GHG emissions as estimated per 'passenger km' (Yeoman *et al.* 2007).

5.4 DATA COLLECTION AND ANALYSIS

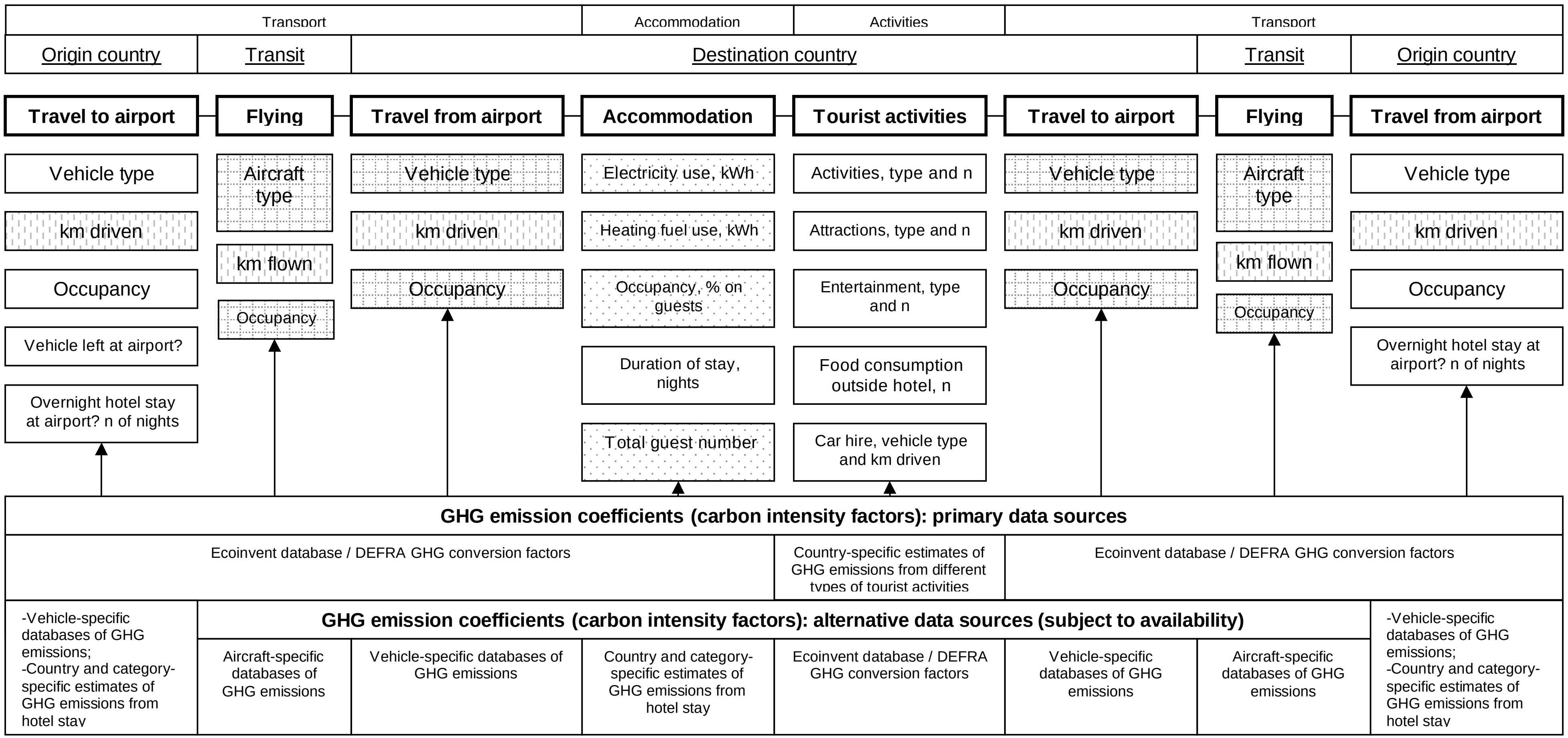
There are various sources of data for LCA (Menzies *et al.* 2007). These include statistical databases, energy use bills, fuel consumption inventories, material and energy flow spreadsheets, expert estimates, interviews with product manufacturers/service providers and surveys. As the holiday package is a composite product, it is unlikely to retrieve the basic data required for holistic analysis of all its elements from a single source. The issue with suitability of the data that LCA traditionally relies upon for accurate carbon impact appraisal of the holiday package also needs to be considered. The problem with data availability, quality and access is deemed to be one of the major reasons why there is so little research on environmental assessment of holiday package tours. Hence, this case study aims to evaluate the data requirements for holistic carbon impact appraisal of the holiday package and outline feasible approaches for data collection.

5.4.1 Data collection

Figure 5.3 introduces the basic data required for carbon impact appraisal of the holiday package in the Algarve and highlights how these have been collected. It is argued that these data requirements can be generalized and applied to other holiday packages with similar parameters.

The primary data are represented by the energy use and fuel consumption figures as these are closely linked to the GHG emissions (Blengini 2009). These need to be collected for all elements of the holiday package. The availability and ease of access to these data significantly vary.

For carbon footprint assessment of tourist accommodation the data on energy consumption in HV Algarve were provided by the hotel management in the form of monthly energy bills. These data represent the year 2009. According to TUI Travel and the hotel management, there are no drastic inter-annual variations in the energy use patterns in HV Algarve (Nick Harper, Group Sustainable Development Executive, TUI Travel PLC, personal communication, 18 March 2011). Hence, it is argued that the data collected can be projected to describe the energy performance of the resort for the year 2010.



- interviewing tourists (for example, a survey on tourist activities);

- interviewing a provider of holiday package, i.e. a tour operator (for instance, TUI Travel);

- interviewing a provider of accommodation, i.e. a hotel (for example, HV Algarve);

- retrieving information from public online (for instance, Google Maps) and printed materials (for example, holiday package brochures).

Figure 5.3. Basic data and data mining approaches for carbon footprint assessment of the holiday package in the Algarve. Source: Author.

Importantly, while acknowledging that the primary energy demand is a more appropriate measure of the carbon implications of energy use in hotels, the data on operational energy requirements in HV Algarve are represented by the end-use energy values as this is what the energy bills contain. These include energy breakdown into electricity and liquefied petroleum gas (LPG). Disaggregation of energy consumption into major end-users (for example, HVAC, lighting, vertical transportation) has not been conducted in this case study. This is because the hotel's energy bills fail to provide this information while an independent energy inventory would require the installation of complex energy measuring devices and continuous monitoring of these systems (Priyadarsini *et al.* 2009). The value of such decomposition is acknowledged as it helps identify the most energy demanding operational services in HV Algarve. Importantly, most tourist accommodation providers are unlikely to have continuous energy monitoring systems (Priyadarsini *et al.* 2009). It is argued that helping hotels reduce their energy use and consequent GHG emissions will require hotels improve their energy data disaggregation.

For carbon footprint assessment of tourist transport, the following basic data are necessary: distance travelled, vehicle type and occupancy. These data were obtained via TUI Travel (travel to/from airport at the destination and travel to/from destination) and tourists (travel to/from airport in the origin country). Distance was calculated with the help of online maps and distance calculation tools.

The carbon footprint from tourist activities has never been holistically assessed (Becken and Simmons 2002). One reason is the difficulty with developing a universal method for inventorization and comparison of tourist activities in different geographical locations (Acott *et al.* 1998). Moreover, the data on tourist activities and consumption patterns when on holiday are generally difficult to obtain. The issue further complicates as the quality of these data is often insufficient for systematic assessment (Becken and Simmons 2002). The list of activities undertaken by tourists at a destination is vast while the selection of tourist activities is highly subjective. Moreover, tourists are generally not prone to share their consumption and behavioural habits with researchers (Hunter 2002). In terms of carbon footprint analysis, the limited interest in tourist activities has also been determined by their arguably small share in the total GHG emissions from tourism. UNWTO (2007) argues that the contribution of tourist activities equates to only 3% of the tourism-induced carbon footprint. Although it is acknowledged that the uncertainty of this estimate is high (UNWTO 2007), thus calling for more research in the domain of tourist activities and their carbon impacts (Becken and Simmons 2002), more accurate carbon assessments are hampered by the difficulties in data procurement. All these factors contribute to the methodological problems of estimating the carbon footprint from tourist activities within the holiday package. The following methodological issue arises: Is it feasible to measure the carbon impact from tourist activities given that

1) they are difficult to quantify and that

2) their carbon share in the total GHG emissions from tourism is deemed to be low?

This study aims to conduct a *holistic* carbon footprint analysis of the holiday package; hence, it is argued that the carbon impact appraisal of tourist activities needs to be conducted to better understand the patterns of consumption behaviour attributable to tourists undertaking ‘all-inclusive’ holidays and to ascertain the level of associated energy use and GHG emissions. It is further argued that a relatively small, purposeful sample of tourist activities will give an insight into the range of consumption behaviour of tourist activities in the Algarve ranging from those tourists who do not undertake any tourist activities apart from those offered by the ‘all-inclusive’ holiday package (i.e. ‘low consumption’ tourists) to those tourists who undertake a large number of additional activities which are not included into the holiday package they have purchased (i.e. ‘high consumption’ tourists).

These data can be used for modelling the carbon footprints of the ‘low consumption’ to the ‘high consumption’ tourist profiles in the Algarve. The tourist survey also outlines the ‘average consumption’ profile of the package tourists sent by TUI Travel to HV Algarve. It also contributes to better understanding of the relative carbon significance of tourist activities compared to other elements of the standard short-haul holiday package. Last but not least, the share of the ‘indirect’ GHG emissions in the total carbon footprint from tourist activities is revealed.

To this end, a relatively small, purposeful sampling strategy was employed. Forty six interviews were undertaken with respondents purposefully selected to encompass, as far as possible, the range of tourist activities available at the Algarve destination. As this is pilot research on the holistic carbon impact appraisal of tourist activities within the holiday package, its main objective is not to estimate the GHG emissions from tourist activities with the finest degree of precision, but to demonstrate how reliable and accurate estimates can be made and to test the sensitivity of the tourist activities share between low and high consumption tourists. To identify the major issues related to the data collection and carbon footprint assessment of tourist activities along with possible solutions is another important objective of this tourist survey.

The interviews with tourists were conducted on the last day of their stay at HV Algarve. It is argued that a survey among tourists leaving the resort is more accurate as it documents their 'actual', rather than 'planned' or 'envisaged', consumption behaviour which is based on ex-post-reporting of respondents. Similar approach was employed by Dolnicar *et al. (*2010) to obtain an insight into the travel behaviour of Swiss tourists.

Importantly, interviews with tourists are required not only to retrieve the basic data on tourist activities. They are also necessary to obtain the supplementary data for more accurate carbon impact appraisal of such indispensable element of the holiday package in the Algarve as travel to/from airport in the country of origin. This is because the established carbon intensity figures for transport from the GHG emission inventories are based on the averaged values. For example, the carbon intensity coefficient for the 'passenger car' transport category used by the established life cycle database Ecoinvent assumes the average (small) car and the average occupancy of 1.6 passengers per vehicle (Doka 2009; Spielmann *et al.* 2004). Many specific tourist journeys by 'passenger car' do not meet this pattern as they can be made by a large family 'passenger car' (with subsequent higher rates of fuel consumption) with higher occupancies. This will result in different amounts of GHG emissions produced, when estimated per 'passenger km'. This implies that the quality of the carbon intensity figures from the GHG emission inventories can be insufficient to accurately describe individual tourist behaviour. The survey on tourist activities can provide additional information to enhance the accuracy of the original carbon intensity values as tourists can be asked to specify the category of vehicle, distance driven and occupancy. These operational data are used to modify the established values of carbon intensities from the GHG emission inventories to make them more approximate to the reality. For instance, consider that the carbon intensity coefficient for 'passenger car' equates 1 unit of GHG emissions per passenger km and assumes the occupancy of 1.6. Concurrently, the survey on tourist activities reveals the 'real life' occupancy as equal to 3. Hence, the following modification of the original carbon intensity value is necessary: 1 multiplied by 1.6 (this gives the magnitude of the carbon footprint per vehicle) and divided by 3 (this gives the GHG emissions per passenger km). Thus, the tourist survey at HV Algarve asked for details of travel to/from airport in the country of origin (Figure 5.3). The questionnaire used to conduct interviews is presented in Appendix 3.

5.4.2 Data analysis

LCA is a complex method. A number of commercial software packages comprising the detailed and regularly updated databases with pre-calculated magnitudes of environmental impacts have been developed to simplify the appraisal procedure. These databases contain comprehensive information on the environmental performance of many basic manufacturing processes, production and consumption of different energy types and fuels, construction, transportation, waste treatment, etc. The LCA software databases provide holistic estimates of environmental impacts, systematically accounting for all stages of the product or service lifecycle with an option to include/exclude the 'indirect' contribution from the infrastructure and capital goods (Frischknecht *et al*. 2007a).

To perform LCA (LCEA) of the holiday package in the Algarve, SimaPro 7.1 software application (Pre Consultants 2011), an established commercial package for LCA analysis, is used (Appendix 4). The Ecoinvent database (Frischknecht and Rebitzer 2005) is employed for carbon impact assessment because it is broadly recognized as the most consistent and transparent environmental impact inventory for life cycle appraisals which can be applied in a variety of geographical regions (Johnson 2008). The carbon footprint assessment is carried out by inserting the basic data attributable to different elements of the reviewed holiday package (Figure 5.3) into the software. The software then makes all necessary calculations by converting the inserted figures into the established values of the carbon impacts from the Ecoinvent database. If a survey on tourist activities reveals that the averaged values of carbon intensity employed by the Ecoinvent database are based on the operational parameters which are different from the 'real life' situation, the necessary modifications are made (see 5.4.1 for explanation).

The Global Warming Potential (GWP_{100}) indicator, expressed in kg of CO_2-equivalents (CO_2-eq.), which closely correlates to energy use (Blengini 2009), is adopted in this study as a measure of the greenhouse effect according to IPCC (IPCC 2007). Despite recent criticism related to the accuracy of produced estimates (Jardine 2005), this indicator currently represents the main metric for estimating the GHG emissions in international climate policies (Grassl and Brockhagen 2007; Sinden 2009). The time horizon of 100 years is selected as IPCC considers it the most feasible time period for carbon footprint assessment (Pennington *et al.* 2004).

The Ecoinvent database does not account for potential global warming impacts imposed by the radiative forcing (RF) effect, predominantly because significant scientific uncertainties exist in establishing their magnitude (Brakkee *et al.* 2008). Hence, the LCA (LCEA) of the holiday package in the Algarve does not take these into account. The impact of accounting for the RF effect in estimates of the GHG emissions from the holiday package under review will be critically evaluated in the sensitivity analysis.

As there is no consensus in the scientific community on normalisation and weighting as elements of the impact assessment procedure within LCA (Blengini 2009), this study focuses exclusively on the classification and characterisation steps (see 4.2.1). CML 2001, an established LCA characterization approach (Ortiz *et al.* 2009b), is utilized for analysis of carbon impacts due to its broad international acceptance and previous successful application in the 'LCA and tourism' field (De Camillis *et al.* 2008).

5.5 SUMMARY

This chapter has discussed how the holiday package for LCA (LCEA) analysis has been selected. As the holiday package is a composite product, three different functional units have been introduced. The system boundaries for assessment of the direct and 'indirect' GHG emissions have been established following the 'door-to-door' concept. This largely corresponds to the 'cradle-to-grave' principle adopted by the LCA methodology. The data requirements for LCA (LCEA) of the holiday package in the Algarve have been evaluated and feasible data mining approaches suggested. It is argued that these can be generalised for application to carbon impact appraisal of other holiday package tours with similar parameters. The next chapter conducts the LCA (LCEA) inventory analysis of the holiday package under review.

CHAPTER 6. LCA (LCEA) OF THE HOLIDAY PACKAGE IN THE ALGARVE: AN INVENTORY ANALYSIS

6.1 INTRODUCTION

This chapter conducts an inventory analysis of the holiday package in the Algarve following the LCA (LCEA) assessment framework. It introduces the research object (HV Algarve resort) by providing a detailed overview of its organisation along with statistical data on guest numbers and energy use practices. The results of the tourist survey are presented and critically discussed. The basic data gained from the tourist survey are evaluated to better understand the operational characteristics of different elements of the holiday package. The main consumption patterns in relation to tourist activities attributable to the 'all-inclusive' tourists in the Algarve are identified. The individual and average tourist consumption (behavior) profiles are derived.

6.2 THE HOLIDAY PACKAGE IN THE ALGARVE AS A RESEARCH OBJECT FOR LCA (LCEA)

6.2.1 HV Algarve

6.2.1.1. Resort organisation

HV Algarve (also known as Alto da Colina Aparthotel) is a modern build (Table 6.1) which contains two accommodation blocks, Alto da Colina 1 and Alto da Colina 2, and two small wooden structures hosting the hotel's children clubs, an outdoor snack pool bar and an activity shed (First Choice 2009b). The total gross floor area (GFA) of the resort is 17875 m^2. The accommodation block Alto da Colina 1 (GFA = 13125 m^2) is almost 3 times larger than Alto da Colina 2 (GFA = 4750 m^2). This is because Alto da Colina 2 hosts only guest rooms while Alto da Colina 1 also has spacious communal, administration, technical and catering areas. HV Algarve has four heated outdoor and two heated indoor swimming pools with sauna, jacuzzi and fitness centre (Alto da Colina 2010; First Choice 2009b).

The accommodation blocks in HV Algarve have five floors (Figure 6.1) and comprise of 132 apartments (Alto da Colina 2010). The resort is a 'full season' accommodation facility; however in winter season (November-April) its operations are limited and it functions as a standard hotel rather than a holiday complex (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). As a consequence, some of the hotel facilities (for instance, outdoor pools, activity shed and an outdoor snack pool bar) are open only in summer (Alto da Colina 2010).

Table 6.1. Principal characteristics of HV Algarve.

Data are valid for 2009.

Characteristic	
Location	Albufeira, Portugal
Year of construction	2004
Geography type	City
Operational season	300-310 days a year; usually closed November-December
Category	4*
Number of employees	60 (winter season) – 90 (summer season)
Gross floor area (GFA), m^2	17875
Type of building(s)	2 separate accommodation blocks
Number of rooms	132
Number of beds	380 (minimum occupancy); 700 (maximum occupancy)
Energy use (fuel)	Electricity and LPG
In-house facilities	Laundry, 2 restaurants, bar, shop, fitness centre
Number of guests, including	13150
TUI Travel PLC clientele	*8931 (68%)*
Occupancy (%, on rooms),	29
TUI Travel PLC clientele	*96*

The 132 apartments at HV Algarve are represented by standard double rooms (accommodate 2 adults + 1 child), family rooms with double and twin beds (2+2), 1-bedroom apartments (sleeps up to 4 adults) and 2-bedroom apartments (sleeps up to 6 adults) (Alto da Colina 2010; First Choice 2009b). All apartments are air-conditioned and have fully-equipped kitchenettes. In summer season HV Algarve offers accommodation to its guests on the 'all-inclusive' and self-catering bases (First Choice 2009b). In winter season it operates as a traditional 'bed-and-breakfast'.

HV Algarve is situated 900 m away from the sea (First Choice 2009b). It has its own minibus park and provides complimentary shuttle bus services to the beach. On demand, HV Algarve operates paid shuttle minibus transfers to Albufeira old town. Airport transfers are also offered to hotel guests upon request.

The range of recreational activities available to tourists in Albufeira is diverse and includes motorised water and surface activities, excursions, visits to theme and entertainment parks. All these services are independently managed and not offered directly by the hotel complex (Alto da Colina 2010; First Choice 2009b). A detailed analysis of tourist activities in Albufeira is provided in 6.2.3.2 and 6.2.3.3 and Appendices 6-8.

Figure 6.1. HV Algarve.

Source: First Choice (2011).

TUI Travel uses its own charter flights to deliver Britons to the Algarve (via Faro International Airport). These seasonal (May – September) flights are made from the following UK airports: Belfast (1 flight a week), Birmingham (3-4), Bristol (1), Cardiff (1), Doncaster-Sheffield (2), East Midlands (1), Exeter (1), Gatwick (2-3), Glasgow International Airport (1), Luton (2), Manchester (3), Newcastle (1) and Stansted (1) (First Choice 2009). According to TUI Travel, London Gatwick sends the largest number of passengers to HV Algarve (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010).

6.2.1.2. Guest statistics

HV Algarve is a busy resort. In summer 2009, TUI Travel carried 8931 tourists, an average of 343 tourists per week. With this number of guests, the hotel complex reported a 96% room occupancy (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010).

The duration of holiday packages offered to Britons by TUI Travel at HV Algarve varies between 7, 10, 11 and 14 nights (First Choice 2009b) but the average figure of 9.8 nights was typical for summer 2009 (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). The 7 and 14-night stays are the most popular, with shares of circa 40% and 30%, respectively. London airports are the primary departure airports for short holidays while non-London airports service the majority of holidays with longer duration of stay (First Choice 2009b).

According to TUI Travel, circa 70% of the clients delivered to HV Algarve in 2009 were contracted on an 'all-inclusive' (AI) basis (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). Importantly, 'self-catering' (SC) tourists have an option to upgrade their stay to 'all-inclusive' upon arrival to HV Algarve. TUI Travel reports that the portion of SC holidaymakers switching to AI is significant. The more precise figure is however not available as tourists pay for an upgrade direct to the hotel reception, not to TUI Travel (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010).

While in summer season HV Algarve is open exclusively to the TUI Travel tourists from the UK, in October-April it can be booked by anyone. TUI Travel's capacity to bring tourists to HV Algarve in winter is significantly reduced. In 2009, for example, about 100 Britons booked this hotel via TUI Travel (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). Importantly, at this time of the year HV Algarve is also used by other tour operators from different source markets. The total number of guests who stayed at HV Algarve in 2009 equates to 13150 and the average annual room occupancy was reported as equal to 29% (Operations manager, HV Algarve, personal communication, 29 August, 2010). This implies that the majority (circa 70%) of the 2009 season guests came to HV Algarve in summer and via TUI Travel.

6.2.1.3. Energy use practices

HV Algarve consumes energy in the form of electricity and LPG. LPG is utilised for space heating, hot water production and cooking while electricity is used for air-conditioning, lighting, laundry, and other services. In 2009 the hotel complex consumed 1445300 kWh of electricity and 34750 kg of LPG (equating to 443060 kWh [9]) (Figure 6.2) (Operations manager, HV Algarve, personal communication, 29 August, 2010). Importantly, these figures indicate the energy use from *all* hotel guests, including both the summer season TUI Travel and the winter season non-TUI Travel clientele.

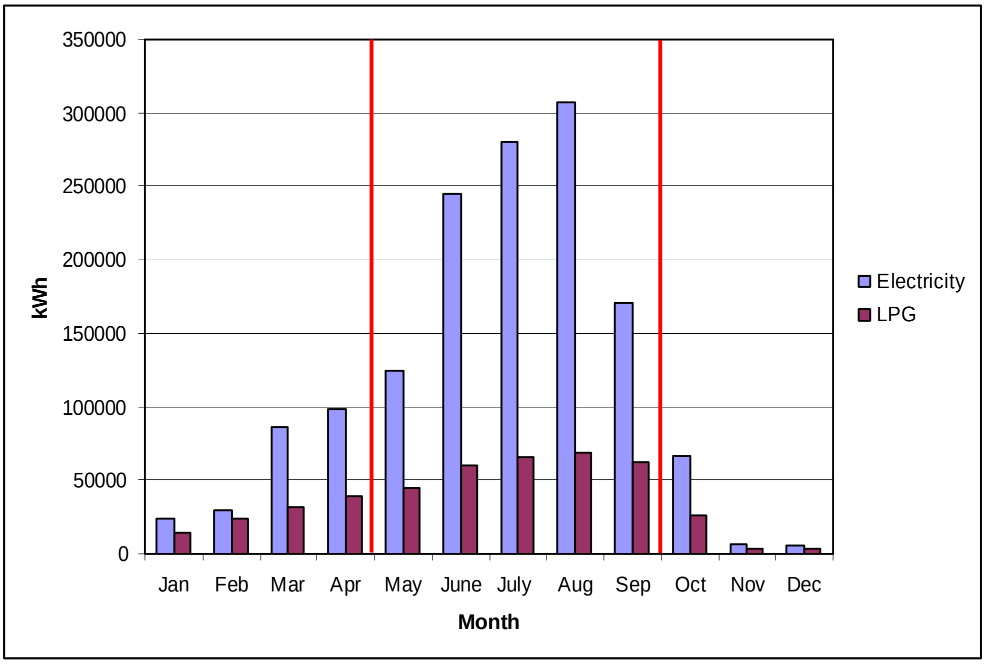


Figure 6.2. Energy consumption in HV Algarve.

Data are valid for 2009.

Energy use per unit of gross floor Area (EUI – Energy Use Index), expressed in MJ/m^2/year or kWh/m^2/year, is one of the indicators broadly employed in the building sector for energy use performance assessment (see 4.5.2). The EUI value of 106 kWh (380 MJ)/m^2/year is typical for HV Algarve in 2009. If this number is compared against the EUI figures from elsewhere, the analysis demonstrates that the resort under review is more energy efficient than the majority of hotels reported in the literature, where the energy use values ranging from 250 to 2570 MJ/m^2/year were found (see Table 4.2). Better energy consumption performance can be partially explained by the currency of

[9] The conversion factor of 1 kg LPG = 12.75 kWh LPG (net calorific value, real world conditions) is used (DEFRA 2010a).

the resort's buildings, limited operational season and, more generally, by the recent improvements in the building energy efficiency achieved in the hotel sector.

This study aims to estimate the GHG emissions from energy use attributed to the summer 2009 TUI Travel holidaymakers. Hence, the fraction of energy consumed in summer 2009 (May-September) was extracted from the resort's monthly energy bills (Figure 6.2). It equates to 1138000 kWh of electricity and 24160 kg (308040 kWh) of LPG. There is a clear correlation between the TUI Travel guests and the energy use in summer. The analysis indicates that the TUI Travel clientele are responsible for about 80% of the annual hotel's electricity consumption and 70% of LPG use. The higher energy use in summer can be partially explained by the more energy-intense activities, i.e. operation of heated outdoor swimming pools, frequent change of bed linen, regular intensive cooking and use of air-conditioning. The higher 'per room' and 'per bed' occupancies in summer 2009 should also have played a role. When calculations of the energy consumed by the TUI Travel clientele in summer 2009 are made on a 'per guest night' basis, the numbers of 13 kWh / guest night for electricity and 0.276 kg / guest night for LPG (equates to 3.5 kWh / guest night) are obtained (James Whittingham, Group Environment Manager, TUI Travel PLC, personal communication, 15 January 2009).

6.2.1.4. TUI Travel, HV Algarve and sustainable development

TUI Travel is applying efforts to cut the carbon footprint from their products. To achieve the GHG emission reductions from air travel, such measures as flying with high-load factors, carrying fewer catering accessories to decrease the weight of the aircraft and using one engine instead of two when taxing around the airport, wherever possible, have been implemented (First Choice 2009a). Furthermore, TUI Travel is committed to update its aircraft fleet with newer, more fuel-efficient, models; it is the UK launch customer for the Boeing 787 'Dreamliner' which is expected to bring a reduction of up to 20% in the current GHG emissions from the company's flights. In recognition of its efforts towards more environmentally responsible tourism practices, TUI Travel airlines (operated under the brands of First Choice Airways and Thomson Airways) were named the 'Most Environmentally Responsible' airlines at the British Travel Awards 2006-2009 (First Choice 2009a). In 2007-2009 TUI Travel also received this award in the category of the 'Most Environmentally Responsible Large Tour Operator' (First Choice 2009a).

TUI Travel is a participant of the Travelife award tourism ecolabelling scheme (TUI Travel 2010). A number of hotels operated by TUI Travel have undergone environmental audits according to the Travelife criteria and been awarded a Travelife logo (First Choice 2009a). HV Algarve has received a Travelife Gold award for the lead in environmental and social responsibility (First Choice 2009a). This is partially because the accommodation blocks at HV Algarve are modern and were constructed according to the most recent insulation standards in the building sector. In addition, the resort uses LPG for space heating which is recognised as one of the least carbon-intense types of the fossil fuel-based energy carriers.

6.2.2 A survey on tourist activities in the Algarve: the respondent profiles

To conduct LCA (LCEA) of the holiday package in the Algarve, the individual holiday behaviour of British tourists needs to be better understood. This provides an insight into the tourist-specific operational characteristics of such holiday package elements as travel to/from airport in the origin country as well as accommodation and tourist activities at the destination.

To achieve this goal, an interview-administered questionnaire (Appendix 3) was distributed on 29-31 August 2010 among the HV Algarve guests. It asked tourists to provide details on the range of tourist activities they undertook during their stay in the Algarve, specify the place of residence in the UK along with the means of transport to/from airport and address some questions related to food consumption when on holiday and energy use at home. Tourists leaving the resort and waiting for airport transfers in the hotel lobby were approached. Only one family member was invited to partake in the survey.

In total, 46 tourists were interviewed. 42 responses were obtained from AI tourists, while 4 – from SC tourists. The interviews revealed that 1 tourist originally booked their holiday on a SC basis but upgraded to AI upon arrival. It is a popular practice among the TUI Travel clientele to make upgrades on site (see 6.2.1.2) and this tourist was classified as an AI tourist. Since only AI tourists are the focus here and because the number of SC interviewees is low, SC respondents were excluded from analysis. Thus, the total number of valid responses is 43. The data obtained from the survey are presented in Appendix 5.

The size of the survey sample, while not large enough to be representative of the whole holidaymaking period, provides a one week snapshot to cover a range of TUI

Travel tourists and activities they have undertaken at the destination. It is argued that this is adequate to provide an overview of the consumption and travel behaviour of AI tourists at HV Algarve. It also offers a range of consumption and gives an indication of GHG emissions from both high and low consumption tourists.

The average weekly number of tourists sent by TUI Travel to HV Algarve in 2009 was reported as 343; this figure includes adults and children (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). This number is comprised of both AI and SC tourists, with the share of the latter category of about 30% (see 6.2.1.2). This implies that approximately 240 weekly hotel guests are represented by AI holidaymakers. Assuming that an average British family consists of 3 members (Department of Energy and Climate Change - DECC 2010) and since only 1 family member took part in the survey, the sample size covers circa 43 × 3 = 129 tourists or 54% of the total weekly number of AI tourists at HV Algarve.

6.2.2.1. Demographic profile of respondents

Males are represented by 17 (40% of the total number of respondents) while females - by 26 (60%) interviewees. This is arguably because females are more prone to partake in surveys than males (Davies 2007). Most respondents (37 or 86%) are people aged between 25 and 44 years with the majority (27 or 63%) falling within the age category of 35-44 years (Table 6.2). All interviewees stayed at HV Algarve as families with children. This demographic profile of interviewees fits the market position of HV Algarve where young and middle age families are targeted as the primary clientele.

Table 6.2. Demographic profile of respondents.

Gender / Age	16-24	25-34	35-44	45-54	55-64	65-74	75+
Female	1	8	15	2	-	-	-
Male	-	2	12	2	1	-	-

6.2.2.2. Duration of stay

7 and 14 nights were reported as the most and almost equally popular durations of stay at HV Algarve, mentioned by 46% and 42% of respondents, respectively (Table 6.3). The average duration of stay for the survey sample is 10.3 nights. This is only slightly (5%) above the 9.8 nights which is an average duration of stay for all holidaymakers sent by TUI Travel to HV Algarve in 2009 (see 6.2.1.2). Thus, it is argued that the representativeness of the survey sample in terms of the duration of stay is fairly good.

Table 6.3. Duration of stay at HV Algarve.

Duration (nights)	7	10	11	14
Frequency	20	3	2	18

6.2.2.3. Transportation to/from airport in the UK

The majority of respondents traveled to/from the Algarve via London Gatwick, which reflects the statistics from TUI Travel. Other airports had a significantly lower passenger carrying capacity (Table 6.4).

Table 6.4. The UK departure/arrival airports and their distances to the Algarve (Faro International Airport).

Distances are calculated via Air Routing International (2011).

Airport	Frequency	Return distance to Faro (km)
Gatwick	23	3374
Manchester	5	3737
Bristol	4	3299
Birmingham	3	3567
Doncaster-Sheffield (Robin Hood Airport)	2	3814
Glasgow (Glasgow International Airport)	2	4226
Belfast	1	3931
Cardiff	1	3279
Newcastle	1	4119
Stansted	1	3548

To estimate the GHG emissions from transportation to/from airport in the UK, respondents were asked for their postcode. The carbon footprint from transportation to/from airport in Portugal was easier to assess as TUI Travel provided free airport transfers as part of the package deal. The airport transfers in Portugal were made by coach while the transportation mode of tourists to/from airport in the UK varied.

The majority of respondents (37 or 86%) travelled to/from airport in the UK by car (with my family) (Table 6.5). This number includes five taxi rides which were also included into this category. Transport by coach and/or train was by far less popular.

Table 6.5. Means of transportation to/from airport in the UK.

Mode of travel	Car	Car (with my family)	Underground	Bus	Coach	Train
Frequency	-	37 (incl. 5 taxi)	-	-	4	2

A popularity of the car with survey respondents may depend on the type of tourists sent by TUI Travel to HV Algarve. Most interviewees are families with children while the literature suggests that tourists traveling in groups would normally prefer non-public means of transportation (Dolnicar *et al.* 2010). It may also be linked to the schedule of charter flights to/from the UK organised by TUI Travel for holidaymakers in the Algarve. Many of the outbound flights in summer 2010 were early morning (First Choice 2009b) which may imply limited availability of public transport. Another factor is convenience as most interviewees are families with children while traveling with children by a (night or early morning) train and/or coach can be inconvenient. Moreover, travelling by coach from the areas outside of London to Gatwick airport often involves changes either in London Heathrow or in London Victoria. This may result in significant waiting times which, again, can be tiresome for children and thus barely acceptable for their parents. Apart from this, family travel to/from airport is closely linked to the price factor. If all family members go on holiday, the total costs of traveling to/from airport by public transport in the UK can be high, especially given that no discounted tariffs are usually available for airport coach/train journeys. Finally, the significant distances covered by some respondents in order to get to/from airport is another explanation for the popularity of car, especially given that long-distance taxi rides at night can be expensive while the costs of parking at some airports can be acceptable if booked in advance. The last argument is partially supported by the evidence that taxi was used to travel some of the shorter distances (12-50 km), although exceptions are also present: one of the longest return distances reported by interviewees, i.e. 485.6 km, was driven by taxi, see respondent code 9 (Table 6.6).

In terms of the carbon footprint, car is the most carbon-intense means of transportation among the surface modes of travel. For the holiday package under review, however, the individual GHG emissions from car travel will be lower than expected. This is because the majority of interviewees travelled to/from airport with their families, which means high car occupancies. This factor needs to be taken into account when estimating the individual GHG emissions from travel to/from airport in the UK. Section 7.2.1.3 outlines the procedure for adjustment of the occupancy factors required for accurate carbon footprint estimates.

Importantly, one of the potential reasons for driving a car to/from airport, i.e. early flight departures, may have caused additional, non-apparent GHG emissions. These are related to the potential overnight stays at airport hotels for those tourists who had to travel long distances in order to catch an early morning flight and/or whose flights arrived late in the evening. This issue is discussed in more detail in 6.2.2.4.

Table 6.6. Return distance to/from airport in the UK[10].

Respondent code	Residence	Postcode	Airport	Return distance (km)
1	Eastbourne	RN21	Gatwick	151.4
2	Blackpool	FY3	Manchester	185.2
3	Winchester	SO21	Gatwick	248.7
4	London	E6[11]	Gatwick	117.1 (where 30.9 by tube)
5	**Manchester**	**M11**	**Manchester**	**35.8**
6	London	SW18	Gatwick	109.5
7	**Birmingham**	**B10**	**Birmingham**	**15.9**
8	Guildford	GU4	Gatwick	109.5
9	**Bournemouth**	**BH1**	**Stansted**	**485.6**
10	Bristol	BS5	Bristol	32.7
11	West Sussex	RN44	Gatwick	84.8
12	London	E12	Gatwick	162.4
13	Corby	NN17	Gatwick	425.9
14	Surrey	GU35	Gatwick	164.7
15	London	SE9	Gatwick	120.5
16	London	E10	Gatwick	165.9
17	Oxford	OX3	Gatwick	255.9
18	Luton	LU2	Gatwick	236.8
19	London	SE23	Gatwick	133.7
20	Ipswich	IP3	Gatwick	333.1
21	**Newcastle**	**NE5**	**Newcastle**	**12**
22	**Rugby**	**CV8**	**Birmingham**	**49.8**
23	Exeter	EX2	Bristol	216.1
24	St. Albans	AL2	Gatwick	231.8
25	Newport	NP16	Cradiff	148.1
26	Wigan	WN1	Manchester	110.1
27	Wolverhampton	WV2	Birmingham	94
28	Sheffield	S21	Doncaster	96.8
29	Chesterfield	S40	Manchester	143.5
30	Edinburgh	EH4	Glasgow	169.8
31	Belfast	BT13	Belfast	48
32	Portsmouth	PO3	Gatwick	193.3
33	Woking	GU21	Gatwick	114.7
34	Reading	RG5	Gatwick	173.2
35	Aberdeen	AB11	Glasgow	496.6
36	Radstock	BA3	Bristol	55.5
37	Swindon	SN3	Bristol	176.1
38	Doncaster	DN7	Doncaster	29.4
39	Peterborough	PE3	Gatwick	418
40	Southend-on-Sea	SS2	Gatwick	197.4
41	Oxford	OX4	Gatwick	266.3
42	Sheffield	S3	Manchester	143.2
43	London	NW6[12]	Gatwick	102.7 (where 16.4 by tube)

[10] Distances for car and coach were calculated by RAC Fuel and Mileage Claim calculator (Royal Automobile Club - RAC 2010). Where several routes were available, the quickest route was selected. Distances for train were calculated by Travelfootprint Distance and Journey Emissions calculator (Travelfootprint 2010). London Victoria Railway Station was used as a transit station for non-direct routes. Pale grey colour indicates journeys made by coach. Darker grey colour corresponds to train journeys. Bold font indicates journeys made by taxi (categorised as 'car with my family' travel option). No colour entries are journeys by car ('with my family').

[11] East Ham Underground Station was used as a starting point for this journey itinerary.

[12] Kilburn Underground Station was used as a starting point for this journey itinerary.

A low popularity of coach travel is, at first glance, a surprise, especially given that the National Express Group, a major provider of long-haul coach journeys and airport transfers in the UK, offers airport transfers which cover broad geographies. Again, it is deemed that the convenience and price factors played a decisive role in why the coach travel was largely ignored by respondents.

The infrequent use of train, one of the least carbon-intense travel options, can be explained by the cost and the 'early morning service unavailability' factors although its extremely low share in the total number of responses (2 or 5%) is quite surprising, especially given that the majority of interviewees flew from Gatwick airport which has good rail connections with London and its surroundings. No reported travel by bus may have been determined by the insufficient service frequencies in early morning hours when many charter flights were scheduled for departure. It also reflects a low percentage of tourists using the very local to the place of their residence airport.

6.2.2.4. Travel distance to/from airport

To estimate the actual GHG emissions from travel to/from airport in the UK, the return distance is required. It can be converted into carbon footprint via travel mode-specific carbon intensity factors (Becken and Simmons 2008). For travel distance measurements, a map was produced to localise the survey respondents (Figure 6.3). The analysis indicates that the longest return travel distance equates to 496.6 km (itinerary Aberdeen – Glasgow International Airport, driven by car), while the shortest is 12 km (itinerary Newcastle city – Newcastle airport, driven by taxi) (Table 6.6, 6.7). The average return travel distance for all survey respondents was calculated as 168.9 km.

The total distance covered by all interviewees to get to/from airport in the UK equates 7261.5 km where the largest contribution (about 88%) is made by car. Within this category, the share of taxi is 9%, mostly due to the 485.6 km long journey made by respondent 9. The contribution of coach and train is less significant, i.e. 9% and 3 %, respectively (Table 6.7).

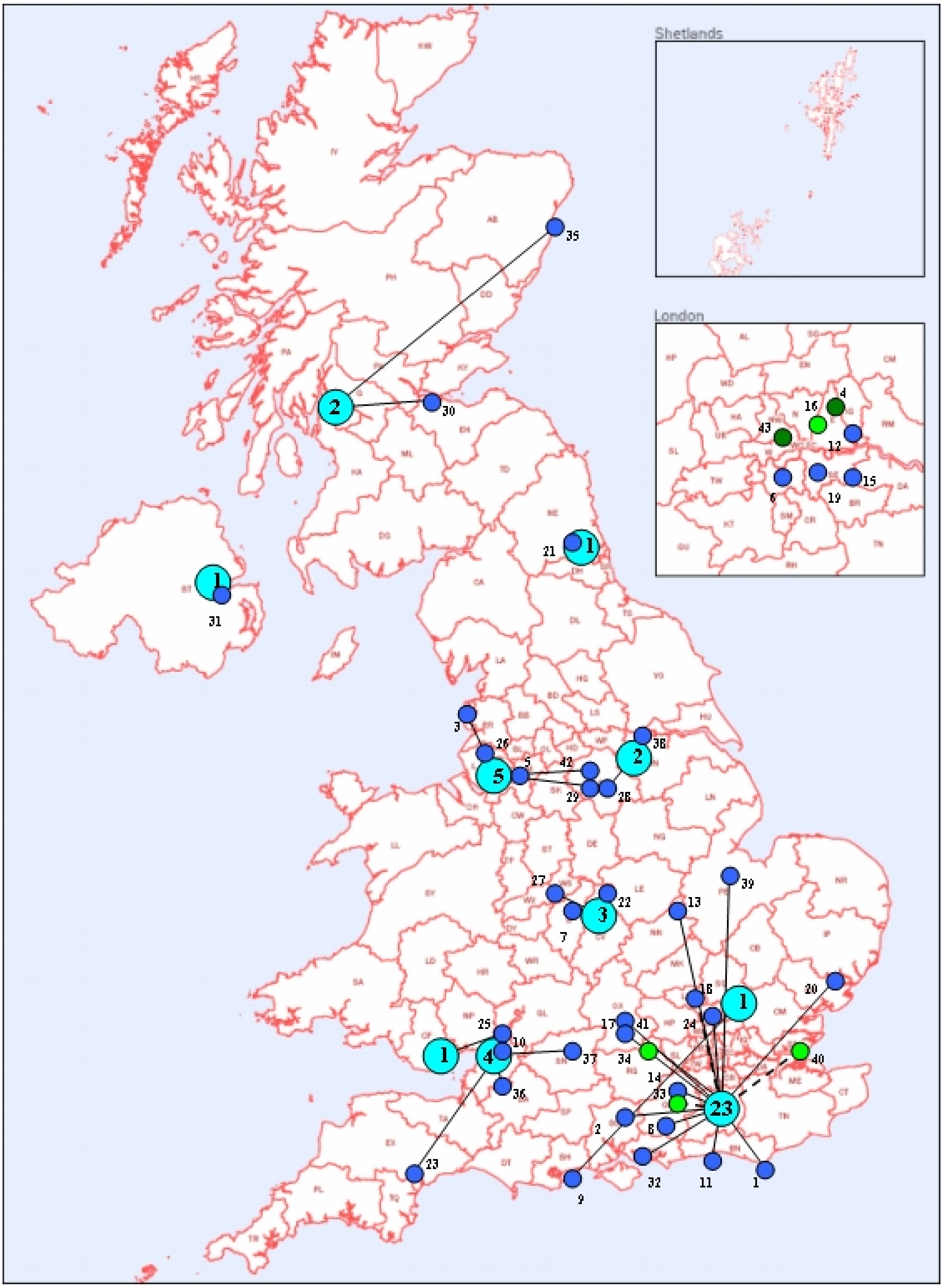


Figure 6.3. Locality of survey respondents.

Large circles indicate departure/arrival airports; the number inside is the total number of recorded arrivals/departures. Small circles show the approximate places of residence. Lines link places of residence to departure/arrival airports. Interrupted lines and/or small circles coloured in light green indicate journeys made by coach. Small circles in dark green indicate train journeys. NB: for residents of Greater London, Gatwick is the only departure/arrival airport. Source: Author. Map adapted from Bruce Jones Design (2010).

Table 6.7. The maximum, minimum and average return travel distances in the origin country.

Travel mode	Min return distance (km)	Max return distance (km)	Total return distance (km)	Average return distance (km), per respondent
Car (with my family), taxi inclusive	12.0	496.6	6390.5	172.7
where taxi only	*12.0*	*485.6*	*599.1*	*119.8*
where car only	*32.7*	*496.6*	*5791.4*	*181.0*
Coach	114.7	197.4	651.2	162.8
Train	102.7	117.1	219.8	110.0
For all modes	**12.0**	**496.6**	**7261.5**	**168.9**

Importantly, Table 6.6 demonstrates that for four interviewees (response codes 9, 13, 35 and 39) the return travel distance to/from airport in the UK is larger than 400 km, with all respondents travelling by car/taxi. Given that such long distances involve extensive car drives, possibly at night, there was a query as to whether these tourists may have stayed overnight at airport hotels. To check this query, the respondents were asked if their travel to/from airport had involved any hotel stays. The survey revealed that the respondents 9, 13 and 39 travelled to the airport by car/taxi at night. Concurrently, the respondent 35 confirmed that they stayed overnight at an airport hotel. While the relative contribution of this overnight hotel stay to the total carbon footprint from holiday travel may be low, this survey has shown that hotels in the origin country can also be part of the holiday travel experience.

It is further argued that a survey on tourist activities is the only way to reveal these additional carbon impacts. Hence, a survey should be conducted among tourists, whenever possible, if the comprehensive carbon impact appraisal of holiday travel is to be performed, to ensure that the total individual GHG emissions from holidays are holistically measured and that none of the elements of a holiday package are omitted. A sensitivity analysis conducted in this study (see 8.2) shows how the share of the carbon footprint arisen from the hotel stay in the UK compares against the total GHG emissions from the holiday package under review.

As for airport transfers in the Algarve, these are organised by TUI Travel. The return travel distance between the Faro International Airport and HV Algarve is therefore identical for all interviewees and equates to 66.4 km (Google Maps 2011), quickest route). This distance was covered by coach.

6.2.3 Tourist activities in the Algarve: an inventory

6.2.3.1. Car rental

Vehicle hire can be an indispensable part of the holiday experience. Car rentals [13] in Albufeira are provided by TUI Travel upon request (via an agent contracted by HV Algarve) and/or by independent agencies located in the vicinity of the hotel and/or in Albufeira old town. Driving a car has a large carbon footprint which may significantly contribute to the total GHG emissions from the holiday package. Hence, interviewees were asked if they had rented a car during their stay at HV Algarve and, if so, what distances had been driven.

The results indicate that six respondents (14%) hired a car (Table 6.8). The relatively low number of car rentals can partially be explained by the AI nature of the holiday package under review. Given that 1) AI packages are often expensive, 2) HV Algarve offers an extensive range of tourist activities for all family members onsite, 3) the beach is situated near the hotel complex and serviced by complementary bus services, 4) other tourist attractions can be fairly easy reached by public transport, 5) public buses and taxi services are cheap in Portugal compared to the UK and 6) car rentals in popular tourist destinations can be costly, it is assumed that the majority of tourists would prefer staying at/near the hotel complex and/or occasionally using public transport or taxi to renting a car and driving around. Further analysis (section 6.2.3.2) shows that this assumption has proven to be correct as most tourist activities undertaken by interviewees had involved taxi and bus journeys. On the other hand, flexibility, a limited frequency of the public transport services in the Algarve, willingness to explore the surroundings on their own, holiday car rental habits, presence of children and travel comfort for the entire family had been mentioned by survey respondents as the reasons for hiring a car.

To estimate the GHG emissions from car rentals, the distances driven are required. For this purpose, respondents were asked to either 1) provide an estimate of the distances they had covered, and/or 2) list the major destinations they had visited by car. In the latter case, the approximate return distance driven was calculated with the help of Google Maps (Table 6.8).

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[13] Apart from car, other vehicles are also available for hire in Albufeira. These include minivans, campervans, motorcycles and motor scooters. However, as the majority of interviewees are families, it is fair to suggest that car is the most popular vehicle to rent.

Table 6.8. Car rentals.

All distance measurements represent total (return) distances. When several routes were available, the quickest route was selected.

Respondent code	Type of car	Car rental duration (days)	Duration of stay (days)	Destinations	Length (km)
5	Small, Volkswagen	3	14	Aquashow family park	35.6
				Slide & Splash aqua park	66.7
				Faro and Algarve	100
				TOTAL	*202.3*
6	Small, Opel	2	11	Faro	65.8
				Slide & Splash aqua park	66.7
				TOTAL	*132.5*
17	Small, Renault	3	14	Lagos, Faro	400
19	Small, Fiat	3	14	Faro, Algarve	300
36	Small, Opel	3	7	Albufeira	100
43	Small, Fiat	2	7	Algarve	300

The analysis shows that three days is the most popular car rental duration. The maximum distance covered is 400 km, while the minimum is 100 km and the average equates to 240 km. If the average driven distance was calculated for the whole survey sample, each tourist would travel approximately 33 km during their stay at HV Algarve.

No strong correlation between car rentals and the duration of stay was found. No further generalisable conclusions can be drawn due to a small size of the reviewed tourist sample.

6.2.3.2. Tourist activities (attractions, entertainment and activities)

Little research exists on environmental assessment of tourist activities, especially with regard to their contribution to the global carbon footprint (Becken and Simmons 2002). The primary focus of existing assessments has been on tourist transportation and accommodation while the carbon impact appraisals of tourist activities are singular and usually based on the approximate estimates rather than on the accurate and consistent ‘real life’ measurements. As a result, Gössling *et al.* (2005) argue that 40 kg of CO_2 can be used as a conservative estimate of the GHG emissions from tourist activities at most destinations. It is however unclear how this value is calculated and what range of tourist activities it covers. Moreover, it is rather dated as based on the studies conducted in early 2000s.

A number of factors determine the little research on the assessment of carbon impacts from tourist activities. Unwillingness of tourists to share their private experience with researchers along with the absence of reliable aggregate carbon impact indicators for popular tourist activities are deemed to be the fundamental factors. In addition, tourist activities are usually not managed by hotels and/or holiday package providers. Environmental assessments of tourist accommodation and tour operators commonly exclude independently managed services and activities from analysis (De Camillis *et al.* 2010). At the same time, better understanding of tourist activities and their carbon footprints enables a more holistic analysis and more accurate estimates of the GHG emissions from a holiday package. This survey aims to identify the range of tourist activities undertaken by the TUI Travel clients in the Algarve with further holistic assessment of their carbon significance and analysis of the relative role they play in the total GHG emissions from the holiday package.

Tourist activities in the Algarve can be booked either via TUI Travel (who, in turn, make reservations via the HV Algarve contracting parties) or via independent agents. Some tourist activities can also be undertaken by tourists on their own. Appendix 6 provides an overview of popular tourist activities in the Algarve.

To estimate the GHG emissions from tourist activities, the following data are required:

1) actual range of tourist activities undertaken by individual tourists;

2) carbon intensity of specific tourist activities;

3) carbon intensity of transportation to/from the place where a tourist activity commences/is organised/takes place.

The survey on tourist activities aimed to address the data requirements 1 and 3. Appendix 7 presents the survey results. Travel distances related to tourist activities are calculated with the help of Google Maps (Google Maps 2011). Only fossil fuel-based travel modes are considered, the carbon-free travel options (for instance, walking) were excluded as they produce no direct carbon footprint. For those respondents who rented a car and identified in the survey questionnaire that car was used to get to/from the place where a tourist activity commenced/was undertaken, the estimates of distance travelled by respondents were taken from Table 6.8 to avoid double-counting.

To fulfill the data requirement 2, the activity-specific carbon intensity indices/GHG emission factors were required. These were retrieved from the literature as direct measurements of energy use and consequent carbon footprints for specific tourist activities in the Algarve were not feasible. These are discussed in sections 7.2.1.1 and 7.2.1.2.

Appendix 7 provides a detailed analysis of tourist activities undertaken by interviewees in the Algarve. The major findings can be summarized as follows:

1. Each tourist undertook, on the average, 3.7 tourist activities. The maximum number of tourist activities undertaken by a single tourist equates to seven while some holidaymakers did not partake in any tourist activities at all.

2. 'Visit to the beach' is the most popular tourist activity which has been undertaken by 79% of respondents. On the average, two visits to the beach were made by each interviewee. While this tourist activity does not directly result in GHG emissions, transportation to the beach does.

3. Visits to the amusement (entertainment, theme) parks and shopping are the second and third most popular types of tourist activities in the Algarve. Apart from the direct GHG emissions from these tourist activities, additional carbon impacts are imposed by their transportation element.

4. There is a correlation between the number of tourist activities and duration of stay at HV Algarve. The average number of tourist activities undertaken by 14-night tourists is 5 while the average number of tourist activities undertaken by 7-night tourists equates 3.

5. Tourists staying at HV Algarve longer have a tendency to partake in more activities with potentially higher carbon footprints, i.e. visits to the amusement (entertainment, theme) parks, motorised tourist activities and long-haul excursions.

6. Distances travelled by tourists at the destination in relation to tourist activities can be significant. The average distance per respondent equates 61.7 km. A significant contribution to the total distance traveled can be made by long-haul excursions. In the reviewed sample this type of tourist activities was undertaken by two interviewees. If these are excluded, the average distance traveled at the

destination by survey respondents equates to approximately 31 km. The largest contribution was made by bus (over 20 km).

6.2.3.3. Dining out

Although the holiday package under review is an AI package, some AI tourists might have dined outside HV Algarve. This enhances the total magnitude of GHG emissions from the holiday package due to additional energy requirements for cooking. Limited research exists on the food consumption habits of tourists in general and on the food consumption behaviour of AI tourists in particular. Hence, a survey on tourist activities has also aimed to plug this knowledge gap by providing an insight into the dining habits of AI holidaymakers at HV Algarve.

Appendix 8 contains a detailed analysis of dining patterns revealed by the survey. The primary findings can be summarized as follows:

1. Despite the 'all-inclusive' nature of the holiday package in the Algarve, respondents tend to regularly dine outside the hotel. The average number of 'eating out's equates to 2. The maximum number of dining out is 5.

2. There is a correlation between the number of 'eating out' and the duration of stay at HV Algarve. Tourists staying longer (14 nights) tend to dine outside the resort more often (3 times on the average), compared to short staying (7 nights) holidaymakers (1 time on the average).

3. Tourists tend to dine out in the vicinity of the hotel. The average distance travelled for dining purposes is about 9 km per survey respondent. Taxi is the primary means of transportation.

6.2.3.4. An average 'tourist activities' profile for survey sample

The analysis of tourist activities makes it possible to construct an 'average' respondent profile. It contains the average range of tourist activities and related travel distances for the sample under review (Table 6.9). Some explanations to how an 'average' respondent profile was drawn are necessary:

It is fairly straightforward to assign the average figures of travel distances. These are based on the data from Tables 6.8 (car rentals), Table 4 Appendix 7 (transport related to tourist activities) and Table 3 Appendix 8 (transport related to dining). At the same time, determination of the average range of tourist activities is more cumbersome. Table 2 Appendix 7 suggests that, on the average, interviewees partook in 3.7 tourist activities. For simplicity of analysis, the value of 4 is taken as an average number of tourist activities undertaken by respondents.

Table 6.9. An 'average respondent profile' with regard to tourist activities undertaken by survey respondents.

Tourist activity	Unit of measurement	Value
Car rental	*km*	33
Dining out	*frequency*	2
Transport	*km*	-
related to dining out		-
Bus		0.2
Tax		8.7
related to other tourist activities		-
Bus		21.1
Tax		5.1
Coach		35.5
Activities	*Name, frequency*	-
Attractions	Beach	2
	Aqua and/or entertainment parks	1
Entertainment	Shopping	1
Activities	-	-

Tourist activities should include two visits to the beach as this activity was undertaken, on average, twice by each respondent. It is argued that shopping and visits to aqua and/or entertainment parks should be added to the list as the third and the fourth activity, respectively. Although shopping as a specific type of tourist activities was reported only by a small number of respondents, the total number of shopping trips (i.e. visits to Albufeira old town for shopping purposes) was identified as the second biggest tourist activity after visits to the beach (Table 2 Appendix 7).

As for visits to aqua and entertainment parks, if all visits made by respondents are summed, their total number is significant and shows that at least every second interviewee partook in this type of activities (Table 2 Appendix 7). Moreover, shopping and visits to aqua/entertainment parks are responsible for the majority of bus and taxi journeys related to tourist activities. It is therefore argued that the inclusion of shopping and visits to aqua/entertainment parks to the 'average respondent profile' is fairly justified.

Importantly, when assigning the average distance related to coach travel, the long-haul trips made by the two interviewees who traveled to Gibraltar and Seville (respondent code 10 and 18) were included. It is however acknowledged that these journeys may be rather atypical as they represent the high-end extremes of coach travel as part of tourist activities in the Algarve.

6.2.4 Food consumption on holidays as an element of the 'net' carbon footprint from holiday travel

One of the objectives of the survey on tourist activities was also to better understand the general food consumption habits of tourists. This is because there is an on-going discussion in the literature as to whether or not tourists consume more food on holiday than at home. Another important question is whether this holiday-related food consumption generates any additional environmental impacts.

As part of the discussion, Peng and Guihua (2007) suggest that the carbon impacts imposed by tourists can be divided into two major categories: *increased* and *transferred*. The authors classify those carbon footprints which would not have occurred if tourists had not undertaken a holiday trip as *increased* carbon impacts. These are associated with transportation, accommodation, activities and waste generation at the destination. According to Peng and Guihua (2007), these impacts need to be assessed and quantified. In contrast, the category of *transferred* carbon impacts comprises the impacts indispensable to human life, i.e. food consumption. These impacts happen in any case, regardless of whether humans travel or stay at home; as a result, they are transferred from place to place and occur with or without tourism (Peng and Guihua 2007). The authors further argue that food consumption of tourists at the destination can be classified as a 'transferred' impact and that it should therefore equate to food consumption of tourists at home. This implies that food consumption does not need to be accounted for in the 'net' environmental assessment of impacts from holiday travel, where the 'net' impact is defined as the difference between the environmental impacts induced by tourists at the destination and the environmental impacts they would produce at home.

This approach has found support among other authors (see, for instance, Chenoweth 2009). Budeanu (2007) states that, at the destination, tourists may tend to replicate daily lifestyles of the origin country, also in relation to food consumption. Moreover, the literature suggests that the concept of 'transferred' impacts may be particularly valid for application in those geographical settings where the case study under review is carried out. Hunter (2002) argues, for example, that tourists may have similar lifestyles and consumption patterns if they travel within Europe. This is due to the relatively homogeneous level of this region development. This argument is in line with the concept of 'transferred' impacts proposed by Peng and Guihua (2007).

The criticism of this standpoint arises from the evidence that the same foodstuffs in different geographies may have different carbon intensities (see, for example, Deng and Burnett 2002) implying that equal amounts of food consumed at home and at destination will not necessarily be identical in carbon footprint terms. Moreover, there are significant variations in national diets with consequent differences in carbon requirements for food preparation and/or conservation. Even more skepticism is added by those who argue that tourists may substantially increase food consumption when on holiday (see, for example, Hunter 2002). Furthermore, food consumption patterns differ between individuals and this also imposes criticism. Lastly, the relative socio-economic homogeneity of many geographical regions (and Europe is no exception) can be questioned on closer analysis. Portugal, where the current case study was conducted, is, for example, one of the least developed member states of the EU. Tourists from economically stronger countries like, for instance, from the UK, Germany and Scandinavia, may consume more food when on holiday in Portugal as the costs of dining are lower. Last but not least, the type of holidays undertaken by tourists may also affect the food consumption habits. The 'all-inclusive' holidaymakers may dine more at the destination as unlimited dining is included into the price of their holidays. To summarise, given that no empirical evidence of food consumption among holidaymakers at the tourist destination has been documented and since a limited number of estimates of the carbon footprint from foodstuffs exist in the literature, the concept of the zero 'net' carbon impacts from food should only be employed if the interviews with tourists cannot be conducted. The results obtained from such analysis will represent crude, although within an acceptable degree of uncertainty, representation of reality. It is argued that tourists should be interviewed with regard to their food consumption habits, whenever possible, to improve the overall quality and comprehensiveness of analysis, address the issues outlined above and, thus, reduce the uncertainty of carbon footprint assessments of holiday travel.

As part of a sensitivity analysis, this research aims to estimate the 'net' carbon impacts from an AI holiday package in the Algarve. To test, whether or not the 'zero 'net' environmental impacts from food' approach can be supported by empirical evidence, the question on food consumption by holidaymakers at the destination was included into the questionnaire.

The analysis demonstrates that only 8 or 19% of interviewees report that they consume more food when on holiday. The majority of respondents (35 or 81%) claim that their food consumption habits do not change. This finding is important, especially given that interviewees are the AI holidaymakers. The initial expectation was that the AI package tourists may consume more food at the destination as unlimited dining is already included into the price of the package. The survey results however suggest that the type of a holiday package does not have a considerable impact on food consumption of holidaymakers. Importantly, some respondents complained about the quality of food at HV Algarve and this may have influenced their dining habits when on holiday. However, most of interviewees did not express any negative attitudes to the food served at the hotel; hence, it is fair to suggest that the food quality issues should not have affected the overall food consumption.

Thus, this finding is in agreement with the concept of 'transferred' impacts developed by Peng and Guihua (2007) and further supported by Chenoweth (2009). The significant limitation of this case study is however a relatively small sample size. Although the results are good enough to draw a general picture, more research, on a bigger sample size and with different tourist types, is recommended in order to obtain more empirical evidence for better understanding of environmental impacts arising from food consumption among tourists at the destination.

Another point of interest that this research has revealed refers to food wastage. The AI tourists may have a high tendency to waste food at the destination as they do not need to pay for it. It is deemed that a separate study on actual measurements of food consumed and wasted when on AI holiday would provide helpful insights into this issue.

6.2.5. Energy consumption at home while on holidays

In order to estimate the 'net' environmental impacts from tourism, the survey also aimed to better understand the 'residual' energy consumption of tourists at home when they are away for holidays.

Chenoweth (2009) argues that the 'net' carbon impact from holidays will be affected by the holiday maker's home continuing to be maintained in their absence, although with a potentially significant reduction in energy consumption (Chenoweth 2009). An average

UK resident emits 2.7[14] t of carbon per year from their home and appliance use, thus producing an average of 7.4 kg of CO_2 per day (DEFRA 2007a cited Chenoweth 2009). This implies that being absent from home will entail a reduction of such energy usage, although not usually to zero, as many appliances can be left in a 'stand-by' mode which still consumes energy. Given this residual energy use, Chenoweth (2009) argues that a temporarily unoccupied home might consume, on the average, about 25% of its normal energy use, with this amount being higher in winter and lower in summer. For the UK, this residual energy usage equates to about 1.9 kg of CO_2 per 1 day / night. The savings achieved in energy consumption while being on holiday may therefore be equal to 7.4 kg - 1.9 = 5.5 of CO_2 per night[15] (Chenoweth 2009). This number can be used to calculate the 'net' carbon impacts from holiday travel.

Given that no empirical evidence exists in the literature which would tackle the issue of this 'residual' energy consumption for holidaymakers, and in order to test the applicability of the argument proposed by Chenoweth (2009), tourists were asked if they had left their home electric appliances in a 'stand-by' mode before going on holiday. Importantly, for the comprehensiveness of analysis, the interviewees should have also been asked if they had left heating systems in their homes 'on' as this is quite a common practice in households, especially in winter, to prevent the pipe damage from, for example, freezing. However, since the survey was conducted in summer, it was assumed that heating systems in holidaymakers' homes would be switched off as the ambient temperature in the UK in summer 2010 was rather high. Note that the 'yes' response might have been obtained in the case if someone (another family member and/or a housekeeper) had stayed in the interviewees' homes while respondents were on holiday. It was however assumed that the homes of interviewees were left unattended for the entire duration of their holiday.

The survey demonstrates that a significant number of respondents (19 or 44%) claimed that they did not leave their electric appliances in a 'stand-by' mode at home before going on holiday. However, concurrently, 16 interviewees (37%) argued for the opposite. Given that a significant number of tourists (10 or 19%) remained undefined if they had switched their electric appliances off or not, no reliable conclusions can be drawn on the basis of this information. It is argued that the assumption from

[14] Department of Energy and Climate Change (DECC) and The Clean Planet Trust provide the number of 2 t, if the average household size is assumed to equate 3 people (DECC 2010; Pure 2009).

[15] 4.1 kg if calculations are made on the basis of the estimates from DECC and The Clean Planet Trust.

Chenoweth (2009) can be used for the 'net' carbon footprint analysis in this study as the potential 'residual' GHG emissions from the holidaymakers' homes are negligible compared to the carbon footprint from other elements of the holiday package in the Algarve. However, it is also argued that, under certain circumstances, this 'residual' energy use can affect the resultant carbon footprint of short holiday journeys. This can be the case, for example, for one-day-out leisure trips made by public transport where the GHG emissions from the transport element of travel are low. It is further argued that a more purposeful research, with a larger sample of respondents, is required in the future for useful generalisable conclusions to be drawn on this topic.

Importantly, a comparative analysis of responses to the 'residual' energy consumption at home question and the question about the duration of stay at HV Algarve reveals that tourists with a shorter duration of stay have a higher tendency to leave electrical appliances at home in a 'stand-by' mode than those holidaymakers who stay at destination longer (Table 6.10). This can partially be explained by the safety and psychology reasons as the higher probability exists that the accidental inflammation of an electric appliance happens when it is left in a 'stand-by' mode for a longer time. It is therefore argued that tourists staying at the destination longer are more prone to switch off electric appliances at home, thus making no contribution to the domestic 'residual' energy use.

Table 6.10. 'Residual' energy consumption at home versus duration of stay.

Duration of stay	**7**	**10**	**11**	**14**	**TOTAL**
Total number of responses	*20*	*3*	*2*	*18*	*43*
Number of 'yes' responses	11	1	1	3	16
Number of 'no' responses	6	2	-	11	19
Cannot remember	3	-	1	4	8

6.3 SUMMARY

This chapter has conducted an inventory analysis of the holiday package in the Algarve. The results of a survey on tourist activities have been presented and critically reviewed. The individual and average tourist profiles related to consumption of tourist activities at the destination have been established. The individual travel profiles associated with transport to/from airport in the origin country as an element of a holiday package have been drawn. The issues related to the 'net' carbon impact assessment of holiday travel have been highlighted. The next chapter performs the carbon impact appraisal of the holiday package in the Algarve on the basis of these data.

CHAPTER 7. LCA (LCEA) OF THE HOLIDAY PACKAGE IN THE ALGARVE: IMPACT ASSESSMENT AND INTERPRETATION OF RESULTS

7.1. INTRODUCTION

This chapter conducts the carbon impact appraisal of the holiday package in the Algarve following the LCA (LCEA) assessment framework. It produces holistic estimates of the carbon footprint attributable to different elements of the holiday package whose relative carbon significance are then critically evaluated. The results of the GHG emission estimates produced by (LCA) LCEA are compared against the outcome of the alternative methods for carbon footprint assessment in tourism. A critical review of advantages and shortcomings attributable to different methodological alternatives allows the development of a new, combined approach for making the most holistic and accurate estimates of GHG emissions from tourism products and services.

7.2. ASSESSING THE GHG EMISSIONS FROM SPECIFIC ELEMENTS OF THE HOLIDAY PACKAGE

7.2.1 GHG emissions from tourist activities

7.2.1.1. Tourist activities (attractions, entertainment and activities)

To estimate the carbon footprint from tourist activities, the activity-specific carbon intensity coefficients (GHG emission factors) are required. These were retrieved from the literature as the 'real life' data were not available due to a broad range of tourist activities undertaken by survey respondents in the Algarve. The estimates of the GHG emissions from transportation to/from the place where a specific tourist activity commenced/took place/was organised were also necessary, to holistically account for the whole range of the carbon impacts attributable to tourist activities.

The literature suggests a few estimates which can be adopted to describe the carbon intensity of tourist activities in the Algarve (Table 7.1). The fundamental limitation of these figures is that they are not independently verified as they represent the results of the internal research conducted by environmental consultancies. Moreover, the focus of these estimates is on Australia and New Zealand. This implies that application of these values in other geographies must be made with caution. No carbon impact assessments of tourist activities with a focus on Europe were identified.

Table 7.1. Estimates of GHG emissions from tourist activities.

Tourist activity, as classified in the literature	Corresponding tourist activity from the package under review	kg CO_2 or CO_2-eq. per activity/visit	Data from	Source
Amusement and theme parks	Aquashow family park Aqualand family park	1.51	New Zealand	Landcare Research (2010)
Aquariums, aqua parks	Slide & Splash aqua park 'Zoomarine' complex	1	Australia	ST CRC (2010)
Motorised water activity (including jet boating and scenic boat cruises)	Parasailing Jet skiing Boat cruise	15.3	New Zealand	Becken and Patterson (2006)
Shopping, casino, bar	Shopping	0.59	New Zealand	Landcare Research (2010)
Wine trail	Jeep safari	27.6[16]	New Zealand	Becken and Simmons (2002 cited Chenoweth 2009)

Another issue is that no public value of carbon intensity for jeep safari tours, popular with survey respondents in the Algarve, was found in the literature. To address this shortcoming, a tourist activity with a similar carbon footprint whose estimate would be available to the public was identified. This task was complicated as no information was provided by interviewees on the distance covered in safaris. It is fair to suggest that jeeps produce significant amounts of GHG emissions; hence, a 'wine trail' tour, which is recognized as the most carbon intense surface tourist activity (Becken and Simmons 2002), was adopted as an equivalent to jeep safari tours in this study. Indeed, in operational and organisational terms, a 'wine trail' tour is fairly similar to jeep safari as it usually takes the form of a regional sightseeing tour undertaken by a small group of tourists on a minibus. The major weakness of this approach is that jeeps are considerably more carbon intense than minibuses; hence, a GHG emission coefficient from 'wine trails' may underestimate the carbon significance of jeep safari tours. Another weakness is however that 'wine trails' may cover larger distances compared to jeep safaris, thus overestimating the carbon footprint of this tourist activity.

The primary carbon footprint from excursions stems from tourist transportation to/from the destination. The approximate excursion distances were therefore measured (Table 1 Appendix 7) and the GHG emission coefficients attributable to the corresponding transportation modes were applied for analysis. The carbon footprints from tour guiding services and tourist visits to attractions and restaurants, while on excursions, were

[16] To obtain this value, Chenoweth (2009) used the estimate of energy intensity proposed by Becken and Simmons (2002) which was converted into CO_2 emissions by using the global average GHG emission factors for energy use.

excluded for the purpose of data unavailability. A similar approach was employed to estimate the GHG emissions from 'visits to the beach'.

There is no agreement in the literature on how to assess the GHG emissions from shopping. The value of carbon intensity from Table 7.1 is rather generic as it estimates the carbon footprint from a single visit to shops, casinos and bars. There is another assessment approach which links the GHG emissions from shopping to the monetary value of purchases made (ST CRC 2010). It suggests that 2.64 kg of CO_2-eq. are produced per each £1 spent. As personal finances is a sensitive issue to discuss during interviews, no question on the amount of money spent for shopping was included in the questionnaire. It is therefore argued that the New Zealand-specific value utilised in this study is accurate enough, especially given that the individual carbon footprint from shopping can be small in such a popular tourist destination as the Algarve. This is due to a significant number of tourists visiting local shops on an annual basis. It is however acknowledged that the total carbon footprint for those respondents who reported 'shopping' as a tourist activity they had undertaken is thus slightly underestimated in this study.

Two interviewees referred to onsite 'mini-golf' and 'sport' as tourist activities. The resultant GHG emissions from these activities were not assessed. This is because 1) both types of activities were undertaken on site (in the hotel's gym and/or on the hotel's sport grounds) which suggests that the associated energy use and carbon footprint will be accounted for when estimating the GHG emissions from accommodation at HV Algarve and 2) their carbon footprint can be negligible as they are small in scale and number and do not cause any direct carbon emissions. Indeed, playing mini-golf does not result in significant energy use (in contrast to the traditional golf where energy is required, for instance, for watering a golf field) as a sport ground for mini-golf is compact and often made of artificial materials. This notwithstanding, there is evidence that sport activities (mini-golf inclusive) may produce up to 17 kg of CO_2-eq. per person/activity (ST CRC 2010). However, such evidence is singular and the study does not provide details of how this estimate is produced.

In general, it is acknowledged that the GHG emissions from all tourist activities reviewed in this study can be slightly underestimated. First, the figures reported in the literature do not account for energy losses and consequent additional carbon requirements related to energy transmission and distribution (Becken and Patterson 2006). According to DEFRA (DEFRA 2010a), these may be responsible for up to 10% of the total consumed energy and GHG emissions. Second, some figures are dated as they are based on the GHG conversion factors developed in early and mid-1990s (Becken and Patterson 2006). Third, in some cases only CO_2 emissions are considered while other greenhouse gases are omitted. Fourth, some estimates are New Zealand-specific. Energy generation in New Zealand is less carbon-intense than in other countries because of a larger share of renewables in electricity production (Becken and Patterson 2006). All this implies that the carbon intensity of the electricity-driven tourist activities in New Zealand is lower than the carbon intensity of these tourist activities in other countries where the share of renewable energy in the national energy balance is less significant.

The latter problem can be solved if the original values of energy intensities for tourist activities are known and if the country-specific GHG emission factors are further applied for their conversion to the consequent carbon impacts. However, the estimates produced by Landcare Research (2010) and ST CRC (2010) do not provide the original energy intensity values. Hence, the carbon intensity coefficients suggested by these sources will be used without any further adjustment. It is deemed to be acceptable as the carbon intensity of specific tourist activities estimated by Landcare Research (2010) and ST CRC (2010) is low, i.e. 0.59-1.51 kg of CO_2-eq.

In contrast, the energy intensity values for motorised water activities and wine trails (equivalent to jeep safari tours in this study) were found in Becken and Patterson (2006) and Becken and Simmons (2002). Both activities rely on diesel as a primary energy carrier (Becken and Simmons 2002). Hence, the GHG conversion factors for diesel (net calorific value) developed by DEFRA (2010a) were employed for translating the energy intensities into carbon footprint. These are capable of accounting for the direct and 'indirect' GHG emissions, with transmission and distribution losses included. The results of conversion are presented in Table 7.2.

Table 7.2. Modifications of the carbon intensity indices for the selected tourist activities.

Tourist activity	**Energy intensity, as estimated by different sources, MJ per activity**	**Carbon intensity, as estimated by different sources, kg CO_2 per activity**	**GHG conversion factors, DEFRA (2010), kg CO_2-eq. per MJ**	**Adjusted carbon intensity, kg CO_2-eq. per activity**
Reference country	*New Zealand*		*Portugal*	
Motorized water activity (including jet boating and scenic boat cruises)	202	15.3 (Becken and Patterson 2006)	0.0889	18
Jeep safari (wine trail)	174	27.6 (Chenoweth 2009)		15.5

It is acknowledged that this conversion is not methodologically impeccable. The major issue is that the GHG conversion factors for diesel from DEFRA are UK-specific. However, it is argued that they are more suitable for this study as they are up-to-date and more representative for Portugal than the conversion values from New Zealand. This is because the diesel production across Europe is deemed to be based on a fairly similar technology.

Table 7.2 indicates that the carbon intensity of energy and fuel consumption in Portugal is different from the carbon intensity of energy and fuel use in New Zealand. The carbon footprint from motorised water activities is circa 20% higher in the Portuguese case. This is arguably because diesel production in Europe is more energy-intense than diesel production in New Zealand. The age of the GHG emission coefficients used for conversion of energy intensity into carbon intensity may also have been a source of discrepancy.

Importantly, the carbon intensity figure for jeep safari (wine trail) tours has turned out to be significantly lower when calculated with the help of the GHG conversion factors from DEFRA than the one from Chenoweth (2009). This is because the value suggested by Chenoweth (2009) was obtained by using the *global average* GHG emission coefficients, although these had been never specified. It is argued that the UK-specific carbon intensity factor for diesel is more suitable for analysis.

Thus, it is argued that the adjusted GHG emission coefficients from Table 7.2 should be used for carbon footprint assessment of motorised water activities and jeep safaris in the Algarve. The GHG emission factors from Table 7.1 will be used, unchanged, for the carbon impact appraisal of shopping, amusement and theme parks, aquariums and aqua parks.

7.2.1.2. Dining

To estimate the GHG emissions from dining outside HV Algarve, the carbon intensity factors for preparation of food are required. These were retrieved from the literature as it was not feasible to make direct measurements due to the significant number and diversity of catering services available to tourists in the Algarve. Importantly, the carbon impact appraisal of dining out in Albufeira accounts only for the GHG emissions related to food preparation. The additional 'indirect' carbon footprint embedded in the food supply chain (food life cycle) is excluded due to the absence of the basic data on the consumed food type, quantity, origin, production and delivery methods. It is acknowledged that the magnitude of this 'indirect' contribution can be large (see 2.4.6 for discussion).

The literature suggests different estimates of the GHG emissions from dining, ranging from 0.005 to 29.9 kg of CO_2 or CO_2-eq. (Table 7.3). The significant variance is partially due to the different assessment units.

Table 7.3. Carbon intensity of dining/catering.

Unit of dining activity, as specified in the literature	Factor (kg CO_2 or kg of CO_2-eq. per activity/visit)	Geographic scope of application	Source
Restaurant visit	0.005	New Zealand	Landcare Research (2010)
	2		ST CRC (2010)
Warm meal	4	Global	MyClimate (2010)
Breakfast meal	3.5	Scandinavia	Norwegian household carbon calculator (2010)
Lunch meal	3.8		
Snacks	4.2		
Dinner meal	3.1-29.9 (depending on dietary requirements)		

The units employed by Landcare Research (2010) and ST CRC (2010) are consistent as they both refer to a 'restaurant visit'. However, they are concurrently too generic as they do not specify what this unit is comprised of. Restaurants can be visited for a drink and/or for a meal and the resultant carbon footprint may differ depending on the visit purpose. Given the homogeneity of the units used by Landcare Research (2010) and ST CRC (2010), a significant discrepancy in estimates of the carbon intensity between these two sources is even more surprising.

The unit from MyClimate (2010), i.e. 'warm meal', is rather ambiguous as it may equally reflect dining out in a café/restaurant and/or at home. In addition, it does not specify the type (i.e. breakfast, lunch, dinner) of the meal.

The units from Norwegian household carbon calculator (2010) are easy to understand as they are based on specific meal types. However, these values of carbon intensity have been developed for food preparation in households, rather than in public dining facilities. Another limitation of this source is a drastic discrepancy in the estimate of the GHG emissions from a dinner meal which is claimed to be dependent on dietary requirements. According to Norwegian household carbon calculator (2010), preparation of a vegetarian dinner is almost 10 times less carbon intense than preparation of a meat dinner (Table 7.3). The dramatic difference is because of the higher carbon intensity of meat production.

No Portugal- and/or South Europe specific numbers on the carbon intensity of dining in a café/restaurant were found in the literature. Hence, an independent approach for estimating the GHG emissions from dining out was developed, first tried in the pilot case study of hotels in Poole, UK (see 4.5) and applied for analysis in this study:

Bohdanowicz and Martinac (2007) argue that cooking 1 food cover in a hotel restaurant requires 4-6 kWh of energy. These numbers are in a fairly good agreement with estimates by Deng (2003), who discovered that 1 food cover for hotel catering services in Asia demands 3-10 kWh of energy, and Karagiorgas *et al.* (2007) who found that, in a deluxe Greek hotel, specific energy consumption per lunch equates to 5.5 kWh. It is therefore argued that the average energy requirement for 1 food cover in a café/restaurant may equate 5 kWh.

It is further assumed that natural gas and oil are the primary energy carriers used for cooking in Portugal. Hence, if the GHG emission factor for burning natural gas is employed for analysis (life cycle data from the Ecoinvent database, Frischknecht and Rebitzer 2005), the resultant carbon footprint of 1 food cover then equates to 1.3 kg. This value will be used for carbon footprint analysis of dining out in this study.

7.2.1.3. Car rentals and other transportation

To estimate the GHG emissions from driving a hired car, travelling for tourist activities in the Algarve and getting to/from airport in the UK, the carbon intensity factors for transport from the LCA (LCEA) Ecoinvent database were used (Table 7.4). These factors represent the average GHG emissions for different transport modes in Europe and account for the direct (related to fuel combustion in vehicle's engine) and 'indirect' (related to the vehicle and road infrastructure along with the fuel chain) carbon emissions, i.e. they utilise a holistic lifecycle perspective in measuring the carbon footprint from transportation.

For a comparative analysis of the carbon footprint from the holiday package in the Algarve in general and from its transportation element in particular, the alternative GHG emission coefficients were also employed. These are represented by the GHG conversion factors developed by the Department for Environment, Food and Rural Affairs (DEFRA 2010a) and Gössling *et al.* (2005). These methods were selected for comparison as they operate identical carbon footprint indicators (i.e. GHG emissions per '1 passenger km' or pkm or 'per vehicle km') and have been previously employed for carbon impact appraisal of tourism products. An overview of these techniques is provided in section 2.3.7.

Table 7.4. GHG emission coefficients for surface transport.

All values, unless stated otherwise, are per passenger km (pkm). The figures in brackets for the Ecoinvent and DEFRA methods represent the direct GHG emissions only.

Transport mode / Method	**Ecoinvent database, kg CO_2-eq.**	**DEFRA (2010a), kg CO_2-eq.**	**Gössling *et al.* (2005), kg CO_2**
Bus	0.104 (0.0945)	0.1608 (0.1351) (average local bus)	0.091
occupancy (load factor)	*12 or 19%*	*9 or 15%*	*Not specified*
Coach	0.0519 (0.0456)	0.0364 (0.03065)	0.0217
occupancy (load factor)	*21 or 43%*	*28 or 57%*	*37 or 75%*
adjusted occupancy	*37 or 75%*	*37 or 75%*	*37 or 75%*
adjusted coefficient	***0.0295 (0.0259)***	***0.0276 (0.0232)***	***0.0217***
Passenger car (petrol)	0.2 (0.166) (fleet average)	0.2495 (0.211) (average petrol car), **per vehicle km**	0.091
occupancy (load factor)	*1.6*	-	*2 (or 50%)*
adjusted occupancy	*3*	*3*	*3*
adjusted coefficient	***0.107 (0.088)***	***0.083 (0.07)***	***0.061***
Passenger car (diesel) = Tax	0.177 (0.145) (fleet average)	0.2397 (0.2149), **per vehicle km**	0.091
occupancy (load factor)	*1.6*	-	*2 (or 50%)*
adjusted occupancy	*3*	*3*	*3*
adjusted coefficient	***0.0944 (0.077)***	***0.08 (0.072)***	***0.061***
Train	0.0151 (0.00364) (regional)	0.0651 (0.0565) (national rail)	0.03 (long-haul)
occupancy (load factor)	*17%*	*Not specified*	*60%*

Importantly, the LCA (LCEA), referred to as the 'Ecoinvent method' thereafter as its estimates are based on the GHG emission coefficients from the Ecoinvent database, and DEFRA methods appraise the different dimensions of the 'indirect' GHG emissions from transport. DEFRA classifies the 'indirect' GHG emissions as those associated with the extraction and transport of primary fuels, as well as from the refining, distribution, storage and retail of finished fuels (DEFRA 2010b), so the definition from DEFRA is purely *fuel chain*-oriented. In contrast, the definition from Ecoinvent is broader as, apart from the fuel chain-related carbon footprints, it also includes the GHG emissions from the production, maintenance and disposal of vehicles and road infrastructure (Spielmann *et al.* 2004). This implies that the definition from Ecoinvent is more comprehensive as it covers a wider scope of the 'indirect' carbon impacts.

Notably, Ecoinvent does not clearly distinguish the fuel chain-related 'indirect' GHG emissions. These are embedded into the estimates of the direct (operational) carbon footprints. In case of energy consumption, for example, the fuel-chain related 'indirect' GHG emissions are accounted for in the carbon footprint from fuel combustion in an energy producing plant. The capital infrastructure-related GHG emissions, i.e. carbon impacts attributed to the construction of an energy producing plant are estimated separately. Similarly, in the case of transport, the 'indirect' fuel chain-related GHG emissions are already embedded into the carbon footprints from vehicle operation, i.e. from fuel combustion in a vehicle's engine. The 'indirect' GHG emissions associated with the vehicle manufacture, maintenance and disposal (capital goods production) and road infrastructure construction, maintenance and disposal (infrastructure production) are estimated separately.

Therefore, to avoid confusion, the 'indirect' GHG emissions from DEFRA will be hereafter called the 'fuel chain-related' carbon footprints, while the 'indirect' GHG emissions from Ecoinvent will be referred to as the 'capital goods and infrastructure-related GHG emissions'. The fuel chain-related carbon footprints are not included in this category of the 'indirect' carbon impacts from Ecoinvent. Instead, they are accounted for in the direct (operational) GHG emission estimates produced by Ecoinvent.

Table 7.4 requires some explanations:

General

The method by Gössling *et al.* (2005) estimates the GHG emissions for surface modes of transportation by multiplying the distance travelled by the 1) transport mode-specific GHG emission factors retrieved from various literature sources; 2) detour factor of 1.15 and 3) equivalence factor of 1.05. The values presented in Table 7.4 are final; all required multiplications are embedded.

The method by Gössling *et al.* (2005) does not provide any GHG emission factor for bus travel. Instead, the category 'other' is listed among the transport modes although no explanation is given with regard to what modes of transportation the 'other' refers to. Since all other surface transport modes are covered, it is assumed that the category 'other' can represent travel by bus. If the GHG emission factor from this category is compared against the GHG emission factors of the 'bus' category from other methods, the comparison shows that the figure from Gössling *et al.* (2005) is fairly similar to the number from Ecoinvent (the difference is 12.5%, direct and 'indirect' emissions inclusive), especially if only the direct emissions are taken into account (the resultant difference is then 2%). Both figures are however significantly different from the number proposed by DEFRA. This notwithstanding, in the absence of other estimates, the GHG emission factor from the 'other' category was used for analysis of bus journeys by the method of Gössling *et al.* (2005).

Furthermore, the method by Gössling *et al.* (2005) does not provide estimates of the carbon footprint from taxi travel. It also does not differentiate between different types of fuel; hence, a single GHG emission coefficient from the 'passenger car' transport category quantified by this method was employed for analysis of car and taxi.

Likewise, the Ecoinvent database does not provide separate GHG emission coefficients for travel by taxi. Car travel is represented in this method by the category of 'passenger cars' which are further classified as either being petrol or diesel-driven. As diesel vehicles are currently slightly more fuel-efficient than petrol cars, there is evidence that many commercial vehicles covering large distances on a daily basis (i.e. bus, truck, taxi) rely on diesel (Holden and Hoyer 2005; Narain and Krupnick 2007). Therefore, for carbon footprint analysis of the holiday package, it was assumed that taxis in the Algarve and the UK are diesel-driven. Hence, the GHG emission factors for diesel passenger cars were used for analysis of taxi travel with the help of Ecoinvent.

In contrast, the issues of fuel efficiency are less decisive for car rental companies as a client is responsible for fueling a car, while the corporate image and the quality of vehicles offered for hire are deemed to be more important. Petrol cars are traditionally considered to be more 'up-market' than diesel cars. This often results in a higher popularity of petrol-driven vehicles with car hire providers. In New Zealand, for example, the proportion of petrol cars in the national rental vehicle fleet equals 76% (Becken *et al.* 2008). Hence, the assumption was made that all cars rented by respondents in the Algarve were petrol-driven cars. For simplicity of analysis and given that the difference in carbon intensity of diesel and petrol cars is not drastic (Table 7.4), it was also assumed that interviewees used petrol cars to get to/from airport in the UK. Thus, the GHG emission coefficient for petrol cars was applied to the analysis of car rentals in the Algarve and airport journeys in the UK by the Ecoinvent method. The European fleet average values were used as no data on engine size and market segment of the vehicles were available.

DEFRA (2010a) provides the estimates of the GHG emissions from a regular taxi. These are based on the fuel consumption and consequent GHG emissions from taxis in London (UK). Although the carbon footprint coefficients for London taxis may not be representative enough to estimate the carbon intensity of taxis in other parts of Europe, they will be employed for carbon impact assessment of taxi rides in this study, as no other reliable estimates exist in the literature. It is however acknowledged that these figures can be overestimates, primarily because of the London congestion with consequent small number of kilometers driven per liter of fuel.

As for car journeys to/from airport in the UK, DEFRA (2010a) provide the GHG emission estimates for vehicles of different engine size and market segments. As these variables were unknown, the GHG emission coefficient for an ‘average passenger petrol car’ category was employed for analysis.

For train travel, the Ecoinvent and DEFRA methods are capable of estimating the GHG emissions from different types of trains (for example, regional, long-haul and electric). In contrast, the method by Gössling *et al.* (2005) provides estimates only for long-haul train journeys. This implies that the magnitude of the carbon impacts from train travel measured with the help of this method will be underestimated as long-haul (international) trains are usually more energy and carbon efficient than the regional and national rails. In the case of the Ecoinvent method, the GHG emission factor for regional trains was employed as the return distances covered by respondents were rather short, i.e. circa 110 km. The DEFRA (2010a) method does not provide the GHG emission factor for regional trains; hence, the GHG emission coefficient from the closest related train category, i.e. national trains, was employed for analysis as all train journeys were made within one country. Importantly, all figures produced by DEFRA (2010a) are UK-specific; the numbers from Ecoinvent represent the average European, while the values from Gössling *et al.* (2005) – the average global situation.

Occupancy-related

All methods under review produce estimates of the GHG emissions based on specific average occupancy (load) factors (Table 7.4). These are not specified in the GHG emission inventories and have therefore been extracted from the supporting literature and documentation.

At the same time, the survey on tourist activities in the Algarve has also provided some data on occupancy for specific transport modes. These data suggest that family car journeys to/from airport in the UK had a higher, than the default average occupancy of 50% as proposed, for instance, by the method of Gössling *et al.* (2005). Therefore, the average occupancy factors, employed by the carbon footprint assessment methods under review, have been adjusted to account for this additional survey information, where necessary.

The default average occupancy factors proposed by the reviewed methods were only accepted for estimates of the carbon footprint from bus and train journeys. This is because 1) no information was obtained from the survey with regard to occupancy of these transport modes and since 2) not all methods under review have specified the occupancy factors they have employed for analysis of bus and train travel.

More specifically, only the Ecoinvent (Doka 2009; Spielmann *et al.* 2004) and DEFRA (DEFRA 2010b) methods provide the data on occupancy for bus travel. The estimates of the GHG emissions from bus are based on the assumption that, on the average, there are 12 (Ecoinvent) or 9 (DEFRA) passengers on the bus. The average capacity of a city bus (including seats and standees) equates to 62 (Department of Transport 2009). Then, the occupancy factors are calculated as 19% (Ecoinvent) and 15% (DEFRA).

It is fair to suggest that, in the case of this study, these figures are more applicable to traditional urban commuting (for example, to/from the beach and Albufeira old town), while they may be underestimated for some regional and purpose-specific journeys (for instance, for travel to aqua and/or entertainment parks in the Algarve) where occupancies might be higher as bookings were made in advance. However, since a survey did not reveal any information on the occupancy of bus travel and since the frequency of bus services to/from aqua/entertainment parks was rather high in Albufeira (personal observation), it is argued that the values employed by the reviewed methods are acceptable for analysis. It is however also acknowledged that the carbon footprint from bus journeys to/from aqua, family and entertainment parks in the Algarve may be slightly overestimated by the Ecoinvent and DEFRA methods as a lower occupancy results in higher 'per capita' GHG emissions.

In contrast to Ecoinvent and DEFRA, the method by Gössling *et al.* (2005) does not specify the bus occupancy factor. Hence, it is difficult to assess how this parameter may have affected the estimates of the carbon footprint produced with the help of this method. In general, the method by Gössling *et al.* (2005) provides very limited information with regard to the background data and assumptions it uses for making estimates. Concurrently, it employs the GHG emission factors from a number of different sources, which are not publicly available in English and cannot therefore be accessed direct. This hampers the retrieval of the background data and does not facilitate a comparative analysis against the assumptions applied by other methods under review.

A similar situation can be observed for the occupancy factors for train journeys. While Ecoinvent and the method by Gössling *et al.* (2005) specify these, DEFRA (2010a) does not provide any background information. Concurrently, the estimates of the GHG emissions from train travel by DEFRA (2010a) are significantly higher than the figures produced by Ecoinvent (the difference is over 400%) and the method by Gössling *et al.* (2005) (the difference is in the range of 200%). As no information is available on the occupancy factor employed by DEFRA (2010a), no conclusions with regard to how this parameter may have affected the carbon footprint estimates for train travel can be drawn. Importantly, the values of train occupancy from Ecoinvent (Spielmann *et al.* 2004) and Gössling *et al.* (2005) have a significant degree of discrepancy. This discrepancy relates to the type of trains employed for analysis (regional and long-haul, respectively). As long-haul trains make fewer stops en route and usually have a higher occupancy, they should therefore produce smaller quantities of the 'per passenger' GHG emissions. This suggests that the figure of the carbon footprint from train journeys generated by Gössling *et al.* (2005) is likely an underestimation. It should not however significantly affect the results as train was not a popular transport mode within survey respondents.

The logical algorithm of adjustments for car, taxi and coach is as follows:

1) Most respondents traveled to/from airport in the UK by 'car with my family'. Assuming that an average British family consists of 3 members (DECC 2010) and that the maximum car occupancy equals 4[17] (Penner *et al.* 1999), it is fair to suggest that the occupancy factor of 3 or 75% (3 * 100 / 4) should be employed for the carbon footprint analysis of these car rides.

2) The DEFRA method provides an option of estimating the carbon footprint from car journeys on the basis of '1 vehicle km'. This means that the GHG emission

[17] Note that the maximum car occupancy varies depending on vehicle type and specific model. Large family cars have a load factor of 5+ passengers. The maximum occupancy of 4, which is deemed to be typical for a 'small family car' category, will be used for analysis in this study.

estimates from DEFRA simply need to be divided by the appropriate car occupancy factor (i.e. 3 or 75%) in order to obtain the estimate of the individual carbon footprints.

3) In contrast, the Ecoinvent and Gössling *et al.* (2005) methods estimate the GHG emissions from car journeys on the basis of '1 passenger km'. These estimates account for the average car occupancies which are method-specific, namely 1.6 for Ecoinvent (Doka 2009; Spielmann *et al.* 2004) and 2 (i.e. 50% of the assumed maximum occupancy of 4) for Gössling *et al.* (2005). If the average occupancy of 3 is applied, the estimates from both methods need to be normalised, i.e. multiplied by 1.6 (Ecoinvent method) or 2 (Gössling *et al.* 2005), to obtain the amount of the GHG emissions for '1 vehicle km', and then to be divided by 3, to obtain an estimate of the individual carbon footprints for car passengers. Table 7.4 lists the adjusted (normalised) occupancy factors and resultant GHG emission coefficients for all methods.

It is argued that the same approach should be applied to car rentals in the Algarve. 'Travel comfort for the entire family' was mentioned by interviewees as one of the reasons to hire a car. This may imply that car was rented by families. It is therefore assumed that the occupancy factor for car hire on holidays in the Algarve should be similar to the occupancy of car travel to/from airport in the UK, i.e. 3 or 75%.

It is further argued that the same assumption can be utilised for taxi rides as journeys to/from the beach and/or to/from Albufeira old town may have been made by the entire family. Although a taxi driver increases the vehicle occupancy to 4, it is deemed that the taxi passengers are solely responsible for the GHG emissions from taxi rides. This is because a taxi service cannot be provided without a driver who thus represents some sort of the 'capital infrastructure'. This implies that a taxi occupancy factor should also be adjusted to the value of 3.

Importantly, the adjustment of the occupancy factors has significantly reduced the carbon intensity of car (and taxi) travel. The most noticeable reduction (circa 45-60%) has occurred for the GHG emission factors from the Ecoinvent method. The dominance of car in the carbon intensity hierarchy of surface transportation modes is shaken if the original occupancy factors are replaced with those adjusted to account for the more detailed information on occupancy obtained from the tourist survey. The consequence of such replacement is that journeys by bus produce more GHG emissions per 'passenger km' than journeys by car for the DEFRA (2010a) and Gössling *et al.* (2005) methods while the difference between the carbon intensity of the 'car' and 'bus' transport modes becomes almost negligible in the case of the Ecoinvent method. This finding does not suggest that car is always more carbon-efficient per pkm than bus, but rather highlights that empty buses are very in-efficient in the carbon footprint terms. It also indicates that the data requirements to draw an accurate picture about the GHG emissions from tourist activities are high. A sensitivity analysis is conducted in section 8.2 to better understand how changes in occupancy may affect the total individual carbon footprint from the holiday package.

The adjustment of the occupancy coefficients was also made for coach travel. Firstly, the occupancy factors reported by all methods vary. The one from DEFRA was calculated on the basis of the data supplied by Ecometrica (Gary Davis, Operations Director, Ecometrica, personal communication, 29 June 2010). This consultancy undertakes an annual independent assessment of the GHG emissions for National Express Group, a leading provider of coach journeys in the UK, whose estimates of carbon footprint are used by DEFRA (2010a). The numbers from Ecometrica are based on 57% of fleet average loading, with the average number of 49 seats per coach (Gary Davis, personal communication, June 29, 2010). This means that, on average, 28 seats are occupied on National Express coaches. The Ecoinvent database suggests the average load of 21 passengers per coach (Doka 2009; Spielmann *et al.* 2004). This corresponds to 43% of fleet average loading, if the average number of seats on a coach is assumed to equate to the figure provided by Ecometrica.

Secondly, it is argued that, for the study under review, these original occupancy values from both the Ecoinvent and DEFRA methods are likely to be an underestimation. Coach was reported by interviewees as a primary transportation means for excursions; moreover, it was used for airport transfers organised by TUI Travel. It is deemed that the occupancy figures for excursions and airport transfers should be higher than the occupancy values for regular, fixed route, coach journeys which are taken as a basis for estimates by the Ecoinvent and DEFRA methods. This is because excursions and transfers are less regular and organised on demand; if there is no demand, services can be either cancelled and/or served by vehicles of a smaller capacity (for example, minivans). Moreover, for airport transfers, higher coach occupancy is also due to the presence of several holiday resorts operating under the brand ‘TUI Travel’ in the Algarve. This suggests that the TUI Travel airport transfers are usually not exclusive for guests of a specific hotel and/or holiday village, but used to serve all tourists from the TUI Travel branded hotels in the region (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). Higher coach occupancies are thus closely linked to the efforts applied by a tour operator to maximise its profits. Importantly, the approximate minimum occupancy for airport transfers can be calculated: 343 tourists were sent weekly by TUI Travel to HV Algarve in 2009. Concurrently, there were 20 weekly charter flights organised by TUI Travel from the UK to the Algarve region (see 6.2.1.1). If the assumption is made that 343 tourists are delivered by all 20 flights (equal distribution), the average number of 17 tourists per flight is obtained. This implies that there will be *at least* 17 people (35% loading) on a transfer coach going from Faro International Airport to HV Algarve. Since this coach is likely to be used to serve holidaymakers from other TUI Travel holiday resorts in the Algarve, it is argued that the occupancy factor will be significantly higher than 17 (35%).

Concurrently, the average occupancies for Ecoinvent and DEFRA methods are significantly lower if compared to the occupancy figure used by Gössling *et al.* (2005), i.e. 75%. The precise value of the average number of seats per coach employed by the method of Gössling *et al.* (2005) is however unknown. If the number of 49 seats per coach is taken, 75% occupancy corresponds to 37 occupied seats. It is deemed that this value is more appropriate for estimates of the GHG emissions from coach travel for the survey sample. It is therefore argued that the occupancy factors from the Ecoinvent and DEFRA methods need to be adjusted to account for a more realistic occupancy value of 75%. The methodology used for the adjustment algorithm outlined for the 'passenger car', 'hired car' and 'taxi' categories was applied to coach: the GHG emission coefficients proposed by the Ecoinvent and DEFRA methods were multiplied by the original occupancy factors to obtain the estimate of the carbon footprint 'per vehicle km'. Then, the figure was further divided by 37 to bring it to a common denominator. The results are presented in Table 7.4. Importantly, the adjustment of the GHG emission factors for coach travel on the basis of occupancy has reduced the difference in the magnitude of these coefficients for the Ecoinvent and DEFRA methods. If the discrepancy between the original (direct and 'indirect' emissions) GHG emission factors had exceeded 40%, the difference between the adjusted (normalised) coefficients was less than 10%.

Given that only 4 interviewees travelled to/from airport in the UK by coach, the adjusted GHG emission factors based on 75% occupancy will also be employed for carbon footprint analysis of coach journeys in the UK. It is argued that this should not significantly affect the results as the proportion of the UK-based airport journeys is small and since airport transfers in the UK may have a higher occupancy compared to the traditional inter-city coach journeys due to the less frequent operations.

The discussion above illustrates that the variance in the occupancy values employed by different carbon footprint assessment methods may have a significant impact on estimates of GHG emissions. It is argued that, in future carbon impact appraisal studies, the occupancy factors should be identified and then adjusted (normalised) and/or reduced to a common denominator, where necessary. This reduction can be made on the basis of the data provided by a survey on tourist activities which, apart from occupancy, may also disclose information on specific vehicle and fuel types used by tourists. This improves the accuracy and reliability of estimates. It is further argued that the carbon footprint assessment methodologies should clearly specify the underlying assumptions they had used for estimating the GHG emissions from different transport modes to enhance the transparency, ensure the credibility and facilitate better understanding of the estimates and improve the comparability of results.

This study also shows that a number of different assumptions are employed for carbon footprint assessment of tourist activities. This may serve as a partial explanation as to why tourist activities are characterised by the highest uncertainties among all elements of holiday travel when the estimates of their energy and carbon intensities are made. UNWTO (2007) suggests, for example, that estimates range from a 50% underestimation to 100% overestimation. It is argued that the assumptions utilised for carbon footprint analysis of tourist activities need to be documented and their consequent application should be properly justified. Sensitivity analysis is further recommended to better understand how different assumptions affect the results.

Final GHG emission coefficients

Table 7.5 lists the final (with all adjustments and amendments embedded) GHG emission factors which are applied for a comparative carbon footprint assessment of different elements of holiday travel. It suggests that the variations in estimates produced by different assessment methods are only observed for the transport and accommodation elements of holiday travel while the same GHG emission factors are employed by the methods for analysis of tourist activities, car rental services exclusive. This is because the carbon intensity coefficients for tourist activities were predominantly extracted from the literature.

7.2.1.4. GHG emissions from tourist activities in the Algarve: analysis

Appendix 9 contains the results of carbon impact appraisal for tourist activities undertaken by survey respondents in the Algarve as suggested by different assessment methods. Table 7.6 provides a brief summary of findings. The method-specific, in-depth analysis is presented below.

Table 7.5. Aggregate, final GHG emission coefficients applied to estimate the carbon impacts from the holiday package in the Algarve.

For the Ecoinvent and DEFRA (2010a) methods, both direct and ''indirect' emissions are included while Gössling et al. (2005) quantify the direct carbon footprint only. Aggregate data from Table 7.1, 7.2., 7.4, 7.11, 7.13 and section 7.2.1.2.

Component of holiday travel	**Unit of measurement**	**GHG emissions factor, kg CO_2 or kg of CO_2-eq. per unit of measurement**		
		Ecoinvent	*DEFRA*	*Gössling et al. (2005)*
I. Transportation				
Air travel	pkm	0.154	0.1205	0.147
Bus		0.104	0.1608	0.091
Coach		0.0295	0.0276	0.0217
Personal car		0.107	0.083	0.061
Taxi		0.0944	0.08	0.061
Train		0.0151	0.0651	0.03
II. Accommodation				
Electricity	kWh	0.6	0.56	0.57
Heating		0.25	0.26	0.57
III. Tourist activity				
Aquashow	visit	1.51		
Aqualand				
Slide & Splash		1		
'Zoomarine'				
Parasailing	participation	18		
Jet skiing				
Boat cruise				
Shopping	visit	0.59		
Jeep safari	participation	15.5		
Dining out	visit	1.3		
Car rental	pkm	0.107	0.083	0.061

GHG emissions from tourist activities, LCA (LCEA) method

The carbon footprint assessment by the *LCA (LCEA) method (the Ecoinvent database)* indicates that the total amount of the GHG emissions produced by survey respondents as a result of partaking in tourist activities in Algarve is significant and equates 648 kg CO_2-eq. This is an equivalent of 1.5 kg of CO_2-eq. produced per tourist night.

The 'car rental' and 'activities' categories hold the largest shares, i.e. 24% and 23%, respectively (Figure 7.1). This finding is not surprising as car was hired to drive lengthy distances and because many tourist activities from the 'activity' category are characterised by high energy intensities (Table 7.1). Importantly, within the 'activities' category, all excursions were made either by coach or by bus; if all related GHG emissions from coach and bus travel are added, the share of the 'activities' category in the total GHG emissions rises to over 30%.

Table 7.6. Estimates of the GHG emissions from tourist activities attributed to the survey sample as suggested by different methods.

Analysis parameter / Method	**Ecoinvent**	**DEFRA (2010a)**	**Gössling *et al.* (2005)**
	kg CO_2-eq.		**kg CO_2**
Total GHG emissions	649	657	538
where direct GHG emissions	596 or 92%	602 or 92%	N/A
Attraction	*33*		
Entertainment	*11*		
Activity	*154*		
Bus	*100*	*154*	*87*
Coach	*45*	*42*	*33*
Car rental	*154*	*119*	*88*
Taxi	*56*	*48*	*36*
Dining out	*96*		
Maximum individual carbon footprin	57.5	53.3	48.8
Average individual carbon footprin	15.1	15.3	12.5
where 7 night tourists	*5.8*	*5.4*	*4.4*
where 14 night tourists	*26*	*26.5*	*21.9*
'Average respondent profile' carbon footprint	11.9	12.1	9.6

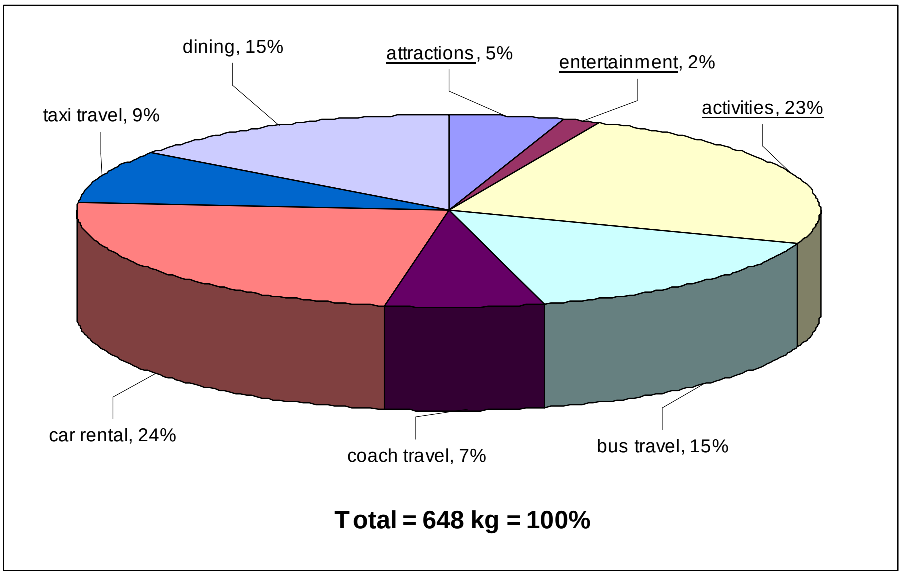


Figure 7.1. The GHG emissions from tourist activities per activity category, Ecoinvent method.

A large share of car rentals in the total GHG emissions from a survey sample is particularly important, given that only 6 respondents (14% of total) hired a vehicle.

Bus travel is the third largest carbon emitter with the majority of the GHG emissions arisen from travel to/from aqua, family and zoo parks. In total, the transport element of tourist activities is responsible for more than half of the total carbon footprint.

The analysis shows that dining outside HV Algarve has produced 15% of the GHG emissions. Importantly, its share grows if the transport element is added. This means that the carbon footprint from catering should not be ignored in tourism carbon footprint appraisal. A survey on tourist activities along with the assessment procedure outlined in this study is deemed to represent a feasible method to obtain the necessary estimates.

Figure 7.1 suggests that the GHG emissions from the 'entertainment' and 'attraction' categories of tourist activities are small. At first sight this may imply that they can be ignored in carbon footprint assessments of holiday travel. However, this finding has to be taken with caution as it has a few limitations. The most important relates to the absence of reliable estimates of carbon intensities for many tourist activities representing these categories (for instance, entertainment parks). The numbers found in the literature and employed for analysis in this study are region-specific and lack external verification. This does not facilitate comparison and hampers a sensitivity analysis. It is argued that more research on the GHG emissions from specific tourist activities, covering a broader range and representing different geographies, is required to address this data gap.

If the average amount of GHG emissions per survey sample is estimated, the figure of 15.1 kg of CO_2-eq. per tourist is obtained (Figure 7.2). Importantly, this value is lower than 40 kg which has been cited as a conservative estimate of the GHG emissions from tourist activities (Gössling *et al.* 2005). It is however unclear how the latter number has been obtained; hence, no conclusions can be drawn on potential reasons for discrepancy.

The maximum estimated carbon footprint from tourist activities is 57.5 kg (respondent code 17), where car hire is responsible for 75%. The second biggest value is 51 kg (respondent code 21) where two energy-intense tourist activities, namely a boat cruise and jeep safari, make a profound contribution of 66% (Figure 7.3). In general, if the top-5 respondents producing the largest quantities of the GHG emissions are analysed (respondent codes 17, 21, 5, 27 and 19), car hire has the dominant share for three of them while tourist activities – for the remaining two. This suggests that reducing levels of car hire on holiday is a major carbon footprint mitigation policy for tourist activities.

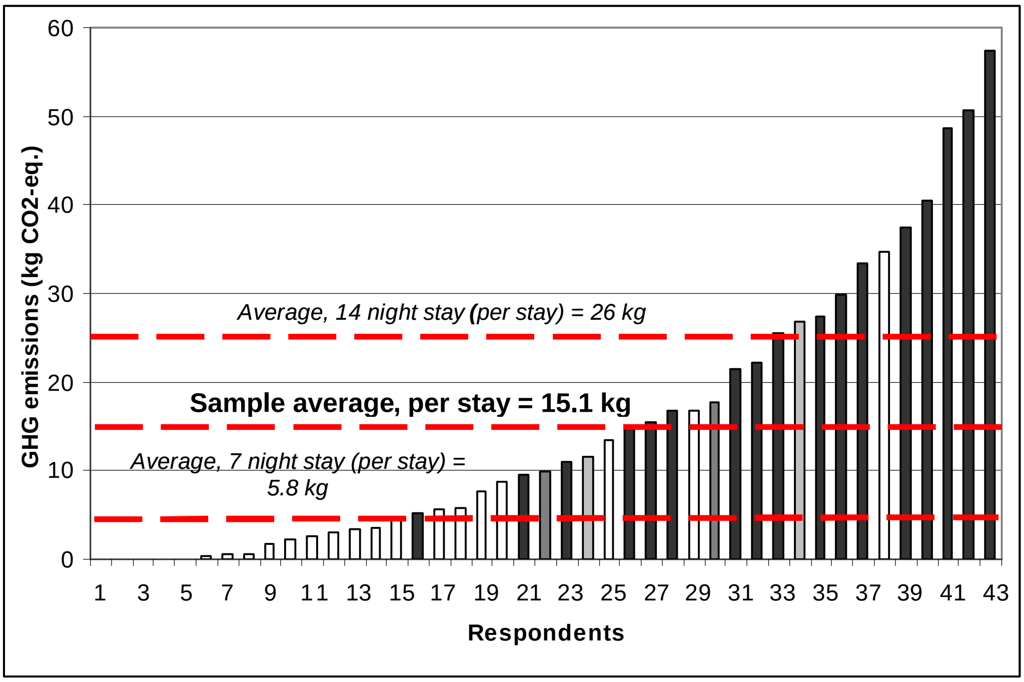


Figure 7.2. Individual GHG emissions from tourist activities, Ecoinvent method.

The intensity of the dark colour reflects the length of stay: white colour represents interviewees with 7 nights of stay; black colour corresponds to respondents with 14 nights of stay. Light and dark grey are tourists with 10 and 11 nights of stay, respectively.

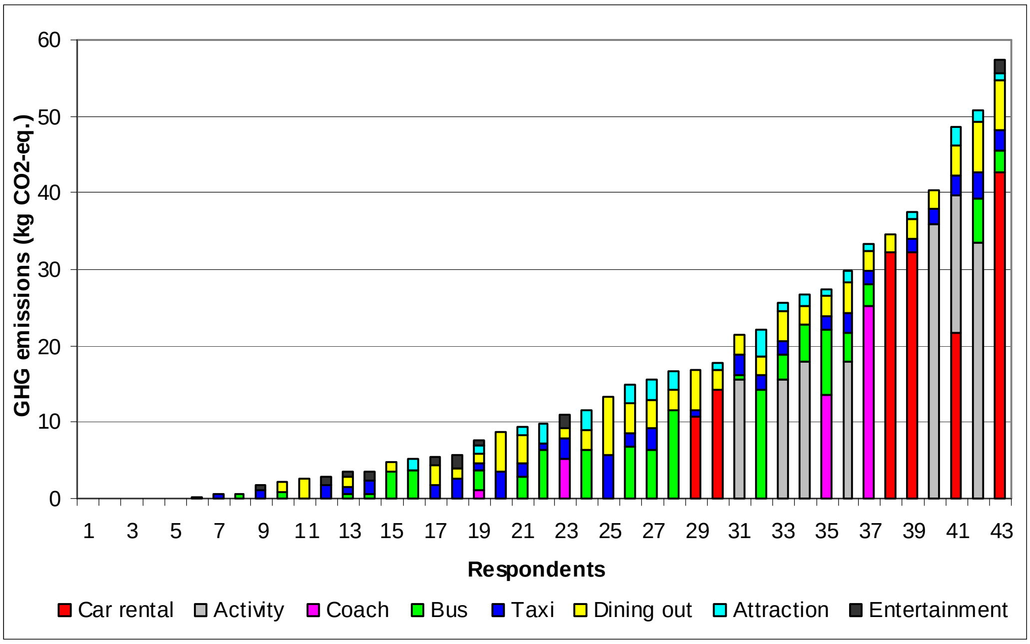


Figure 7.3. Activity-related distribution of GHG emissions, Ecoinvent method.

Further analysis indicates that correlation exists between the amount of the GHG emissions produced and the duration of stay. Interviewees with 14 nights of stay generated 467 kg of CO_2-eq., which corresponds to 72% of the total. Tourists staying 7 nights are responsible only for 115 kg of CO_2-eq. (18% of the total).

If the average amount of GHG emissions is estimated for interviewees staying at the destination 14 nights, the figure of 26 kg per respondent is obtained (Figure 7.2). It is significantly higher than the sample average of 15.1 kg. In contrast, the respondents with 7 nights of stay produced, on average, 5.8 kg of GHG emissions per stay which is 2.5 times less than the sample average. This finding is in line with conclusions by Becken (2008) who argue that a longer stay at the destination may entail a large carbon footprint from tourist activities. If the average carbon footprint is further estimated per tourist night, the figures of 1.9 and 0.8 kg of CO_2-eq. are obtained for 14-night and 7-night staying respondents, respectively. This finding shows that tourists staying at the destination longer not only undertake more tourist activities, but also tend to partake in a larger number of tourist activities with higher carbon intensities. This may relate to more time available and boredom caused by a prolonged stay at the same (often small, like in the case of Albufeira) destination. Indeed, the five top carbon emitters from the survey sample are interviewees with 14 nights of stay. All these respondents either 1) hired a car or 2) took part in motorised water activities and/or jeep safaris. Importantly, there is only one tourist from the '7 night' category whose stay had resulted in the higher amount of the total GHG emissions than the average value (respondent code 43). Over 90% of these GHG emissions stem from car rental (Figure 7.3).

Notably, if the GHG emissions are estimated for an 'average respondent profile' (see Table 6.9), the figure 12 kg of CO_2-eq. is obtained (Table 7.7) which is about 20% lower than the average number of 15.1 kg presented in Figure 7.2. The discrepancy is due to the motorised water activities and jeep safari tours which are small in number (and were therefore not included into the 'average respondent profile') but are very carbon intense. This implies that, if the GHG emissions from a tourist sample are estimated on the basis of the average number and variety of tourist activities they undertook, the results may be skewed and lead to under- or overestimation of the actual carbon footprint, depending on the choice of tourist activities included/excluded from an 'average respondent profile'. This also shows that some active tourists who partake in energy-intense activities when on holiday may significantly affect the magnitude of the total GHG emissions from a tourist sample. It is therefore argued that knowing the average number and variety of tourist activities undertaken by a group of holidaymakers at a specific destination does not necessarily lead to accurate estimates of their average individual carbon footprint. The accuracy will be significantly improved if a survey on tourist activities is conducted, the range of tourist activities available at the destination and undertaken by tourists is inventoried and their GHG emissions (for example, the maximum and the minimum values) are assessed. It is further argued that individual, rather than group-average, carbon footprint is the most reliable measure of GHG emissions from holiday travel.

Table 7.7. Carbon footprint for the 'average respondent profile', Ecoinvent method.

Tourist activity	GHG emissions, kg CO_2-eq.
Car rental	3.5
Dining out	2.6
Transport	3.7
Bus	*2.2*
Taxi	*1.3*
Coach	*0.2*
Activities	2.1
Beach	-
Aqua and/or entertainment parks	*1.51*
Shopping	*0.59*
TOTAL	11.9

Table 7.7 suggests that if the GHG emissions for an 'average respondent profile' are estimated per tourist activity category, car rental is the top carbon emitter. If combined with other travel means, the transport element of tourist activities is responsible for 60% of the total GHG emissions. The contribution of dining out is also significant, i.e. 22%.

To better understand the contribution of the capital goods and infrastructure to the total carbon footprint from tourist activities, the 'indirect' GHG emissions need to be estimated. The estimates provided in this review accounted only for the 'indirect' carbon intensity of the transport component of tourist activities as no data were available on the 'indirect' GHG emissions arisen from energy consumption for specific activities like, for example, motorised water activities. This is because the latter values were extracted from the literature and not measured directly.

When the 'indirect' GHG emissions are estimated for a survey sample, the results show that they account for 8% of the total carbon footprint (Figure 7.4). The 'indirect' carbon contribution is particularly visible for the holidaymakers who traveled extensively at the destination. As for the inter-sectoral distribution of the GHG emissions from transport, the 'indirect' contribution is particularly significant for car rental services and taxis (circa 18%) while it is lower for coach (11%) and bus journeys (9%). This is because 1) the lifecycle of bus and coach is longer than the lifecycle of passenger cars and since 2) bus and coach service more people within their lifecycles than passenger cars. The 'indirect' carbon contribution of holiday travel will be more significant, should the estimates of the 'indirect' GHG emissions be also made for all non-transport elements. Note that the 'indirect' carbon footprint was not estimated for an 'average respondent profile' as its contribution will be negligible due to the short distances traveled and the absence of estimates of the 'indirect' GHG emissions for tourist activities and catering.

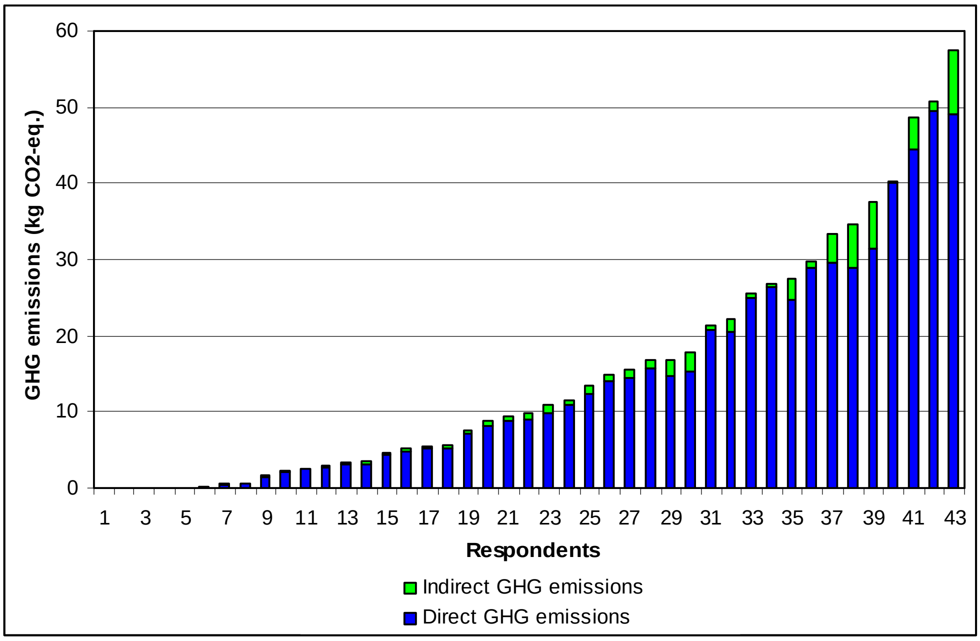


Figure 7.4. The 'indirect' GHG emissions from tourist activities, Ecoinvent method.

GHG emissions from tourist activities, DEFRA method

The analysis shows that the difference in estimates of the GHG emissions from tourist activities attributable to a survey sample made by the Ecoinvent and *DEFRA* methods is negligible, i.e. 649 versus 657 kg of CO_2-eq. As for the contribution of specific categories of tourist activities, DEFRA (2010a) suggests higher figures for bus travel and lower values for car rentals (Figure 7.5). This is a result of the discrepancy in the values of carbon intensity employed by the reviewed methods for these transport modes. The variations within other categories of tourist activities are small.

DEFRA (2010a) estimates the average amount of GHG emissions for a survey sample as equal to 15.3 kg of CO_2-eq. It is only slightly higher than the average value suggested by Ecoinvent. The largest carbon footprint is estimated by DEFRA as equal to 53.3 kg of CO_2-eq. (respondent code 21). In the estimates produced by Ecoinvent the same respondent scores second. This is due to the difference in the GHG emission factors employed by the methods under review for car rentals. This difference can be clearly observed if the individual activity-related carbon footprints are estimated (Figure 7.6). For DEFRA, the interviewees who undertook energy-intense tourist activities have larger carbon footprints than those who hired a car (tourist activities have the biggest share for 3 out of 5 top producers of the carbon footprint) while the opposite situation is typical for Ecoinvent (Figure 7.3).

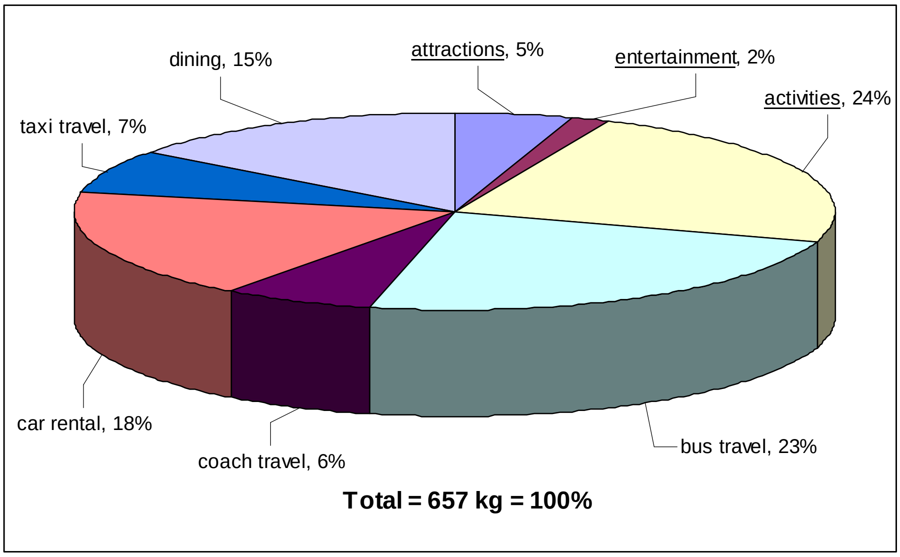


Figure 7.5. The GHG emissions from tourist activities per activity category, DEFRA method.

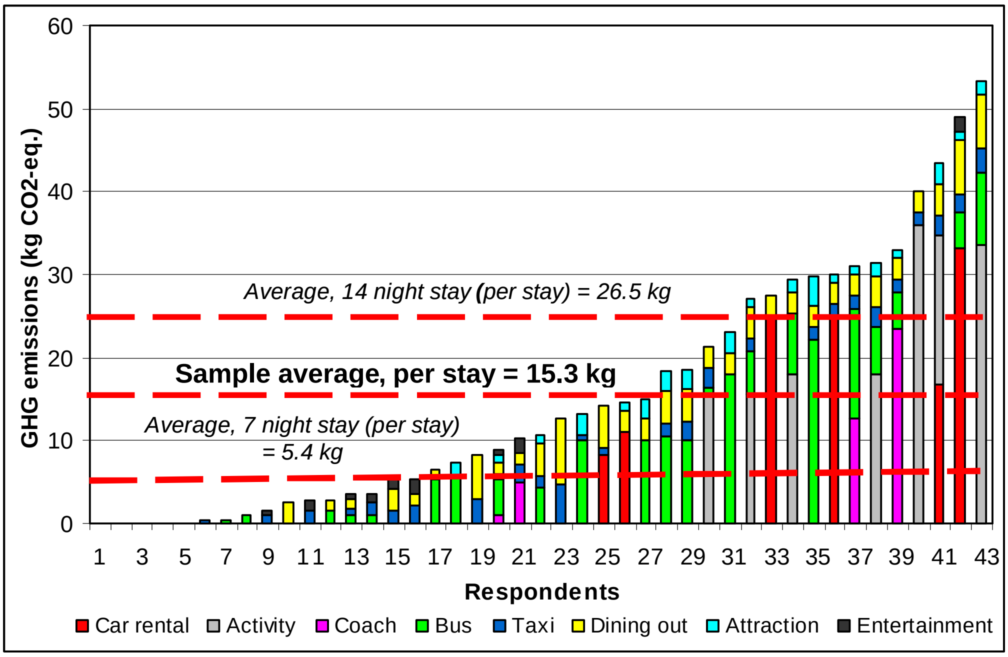


Figure 7.6. Activity-related distribution of GHG emissions, DEFRA method.

The average GHG emissions are estimated by DEFRA as 5.4 kg of CO_2-eq. for tourists staying at HV Algarve for 7 nights and 26.5 kg of CO_2-eq. for respondents staying 14 nights. Again, these numbers are only slightly different from the values suggested by Ecoinvent. The carbon intensity of an 'average respondent profile is estimated by DEFRA as 12.1 kg. The difference from the value proposed by Ecoinvent is negligible.

Similar to Ecoinvent, the 'indirect' carbon footprint from tourist activities is estimated by DEFRA as equal to 8% of the total (Figure 7.7). Car rental, taxi and coach categories hold the largest shares (17%, 16% and 16%, respectively) while bus is characterised by the lowest contribution, i.e. 10%.

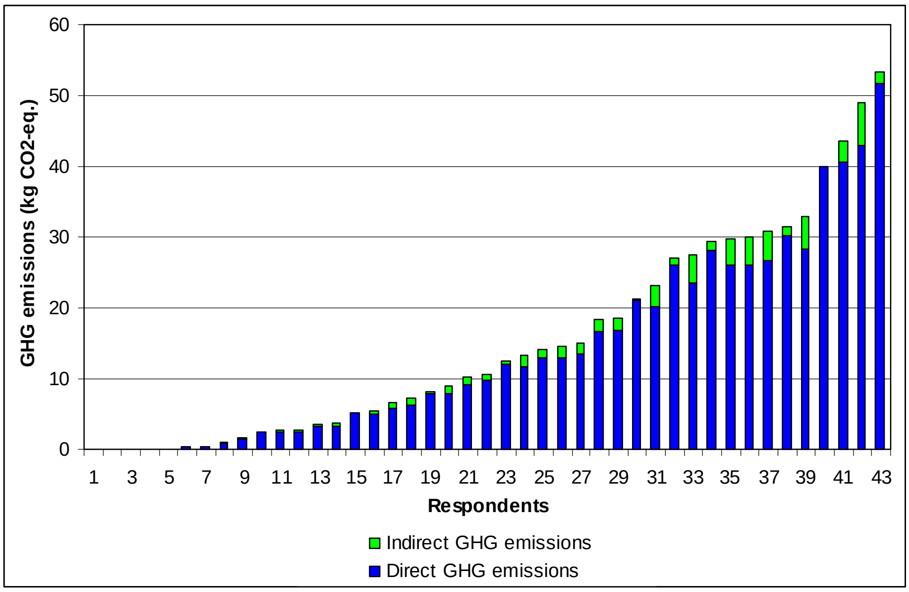


Figure 7.7. The 'indirect' GHG emissions from tourist activities, DEFRA method.

GHG emissions from tourist activities, method by Gössling et al. (2005)

The analysis shows that the estimate of the total carbon footprint from tourist activities produced with the help of the method by Gössling *et al.* (2005) is circa 20% lower than the estimates proposed by Ecoinvent and DEFRA. The most significant discrepancy can be observed in the 'bus travel' and 'car rental' categories where the values from DEFRA (bus) and Ecoinvent (car hire) are almost double the number from Gössling *et al.* (2005). The lower carbon share of bus is compensated by the increased shares of activities and dining (Figure 7.8).

The lower estimates from Gössling *et al.* (2005) are primarily due to its dated and global-average carbon intensity factors. The 'indirect' GHG emissions may also have played a role: Ecoinvent and DEFRA have shown that its contribution to the total carbon impacts from tourist activities equates to 8%. These 'indirect' carbon requirements are predominantly due to the transport element of tourist activities.

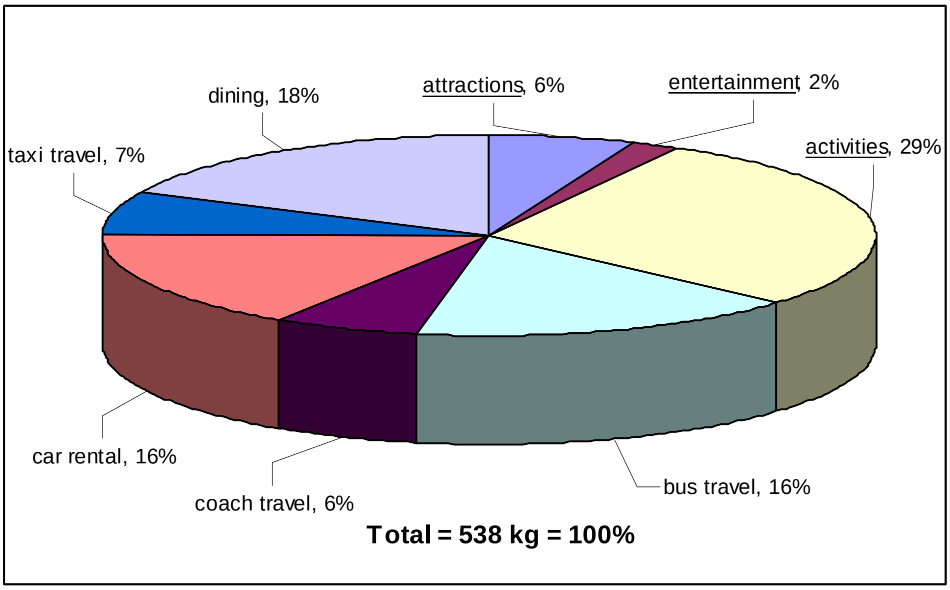


Figure 7.8. The GHG emissions from tourist activities per activity category, the method by Gössling *et al.* (2005).

The maximum value of the GHG emissions is estimated by the method of Gössling *et al.* (2005) as 48.8 kg of CO_2-eq. (respondent code 21) with the average number of 12.5 kg per survey respondent. If the average magnitude of the carbon footprint is estimated for 7 and 14 night respondents, the values of 4.4 and 21.9 kg of CO_2-eq. per stay are obtained, respectively. The carbon footprint of an 'average respondent profile' is estimated as 9.6 kg of CO_2-eq. where dining out and car rental are the largest contributors representing approximately 50%. All these figures are approximately 20% lower than the estimates of the GHG emissions from Ecoinvent and DEFRA.

For individual carbon footprints, the estimates by Gössling *et al.* (2005) suggest that the largest amounts of the GHG emissions were produced by those respondents who took active part in tourist activities (Figure 7.9). This is in a close agreement with the findings from DEFRA but in contrast to the findings from Ecoinvent where the most significant carbon footprint was measured for tourists with car rentals while interviewees participating in energy-intense tourist activities were ranked second (Figure 7.3).

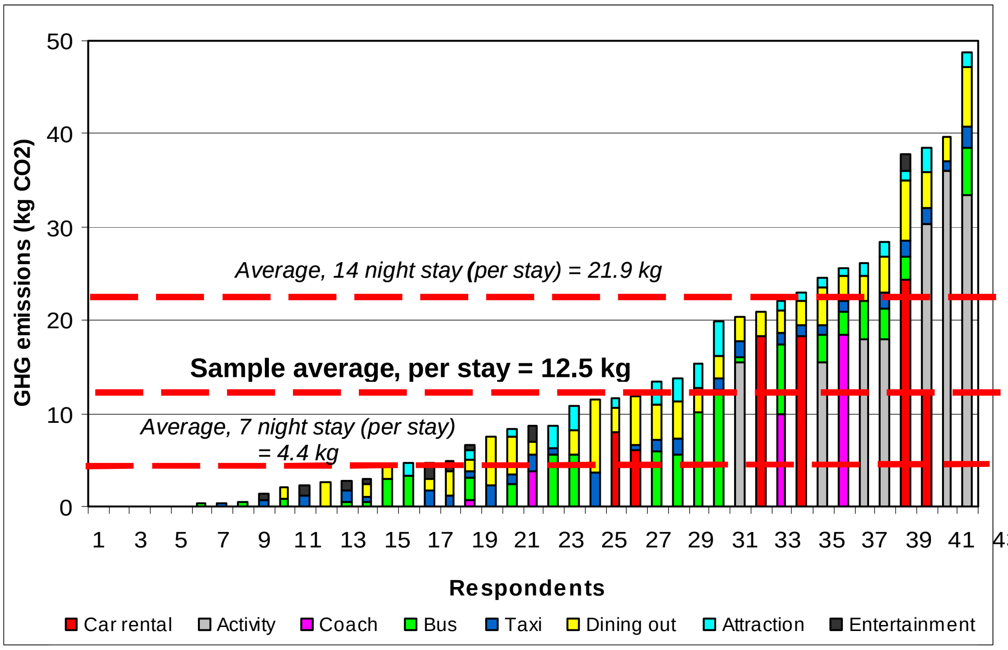


Figure 7.9. Activity-related distribution of the GHG emissions from survey respondents, Gössling *et al.* (2005) method.

7.2.2 GHG emissions from travel to/from airport

Table 7.8 presents the estimates of the carbon footprint from travel to/from airport in the UK as produced by different methods. The analysis shows that the total GHG emissions from the survey sample are significant and vary, depending on the method selected, from 410 to circa 700 kg of CO_2 or CO_2-eq. Ecoinvent suggests the largest estimate while the method by Gössling *et al.* (2005) produces the lowest. The discrepancy of about 70% may arguably arise due to the dated global average GHG emission factors employed for making estimates by the method by Gössling *et al.* (2005).

The average amount of the GHG emissions from airport travel in the UK per survey respondent is 16.25 (Ecoinvent), 13 (DEFRA) and 9.5 (method by Gössling *et al.* 2005) kg of CO_2-eq. The largest carbon footprint was produced by a long-haul car travel from Aberdeen to Glasgow (respondent code 35) equating to 34.7-53 kg of CO_2-eq. The lowest carbon footprint, i.e. less than 2 kg of CO_2-eq., is attributed to short taxi rides and train journeys.

Table 7.8. GHG emissions from travel to/from airport in the UK (kg CO_2-eq. or kg CO_2 per tourist).

Total GHG emissions represent the direct and 'indirect' emissions. Pale grey colour indicates journeys made by coach. Darker grey colour corresponds to train journeys. Bold font indicates journeys made by taxi (categorised as 'car with my family' travel option). No colour entries are journeys by car ('with my family').

Respondent code / Method	Ecoinvent		DEFRA		Gössling *et al.* (2005)
	Total	*Direct only*	Total	*Direct only*	Total
1	16.2	*13.3*	12.6	*10.6*	9.2
2	19.8	*16.3*	15.4	*13.0*	11.3
3	26.6	*21.9*	20.6	*17.4*	15.2
4	1.8	*0.4*	7.6	*6.6*	3.5
5	**3.4**	***2.8***	**2.9**	***2.6***	**2.2**
6	11.7	*9.6*	9.1	*7.7*	6.7
7	**1.5**	***1.2***	**1.3**	*1.1*	**1.0**
8	11.7	*9.6*	9.1	*7.7*	6.7
9	**45.8**	***37.4***	**38.8**	***35.0***	**29.6**
10	3.5	*2.9*	2.7	*2.3*	2.0
11	9.1	*7.5*	7.0	*5.9*	5.2
12	17.4	*14.3*	13.5	*11.4*	9.9
13	45.6	*37.5*	35.3	*29.8*	26.0
14	17.6	*14.5*	13.7	*11.5*	10.0
15	12.9	*10.6*	10.0	*8.4*	7.4
16	4.9	*4.3*	4.6	*3.8*	3.6
17	27.4	*22.5*	21.2	*17.9*	15.6
18	25.3	*20.8*	19.7	*16.6*	14.4
19	14.3	*11.8*	11.1	*9.4*	8.2
20	35.6	*29.3*	27.6	*23.3*	20.3
21	**1.1**	***0.9***	**1.0**	***0.9***	**0.7**
22	**4.7**	***3.8***	**4.0**	***3.6***	**3.0**
23	23.1	*19*	17.9	*15.1*	13.2
24	24.8	*20.4*	19.2	*16.2*	14.1
25	15.8	*13*	12.3	*10.4*	9.0
26	11.8	*9.7*	9.1	*7.7*	6.7
27	10.1	*8.3*	7.8	*6.6*	5.7
28	10.4	*8.5*	8.0	*6.8*	5.9
29	15.4	*12.6*	11.9	*10.0*	8.8
30	18.2	*14.9*	14.1	*11.9*	10.4
31	5.1	*4.2*	4.0	*3.4*	2.9
32	20.7	*17.0*	16.0	*13.5*	11.8
33	3.4	*3.0*	3.2	*2.7*	2.5
34	5.1	*4.5*	4.8	*4.0*	3.8
35	53.1	*43.7*	41.2	*34.8*	30.3
36	5.9	*4.9*	4.6	*3.9*	3.4
37	18.8	*15.5*	14.6	*12.3*	10.7
38	3.1	*2.6*	2.4	*2.1*	1.8
39	44.7	*36.8*	34.7	*29.3*	25.5
40	5.8	*5.1*	5.4	*4.6*	4.3
41	28.5	*23.4*	22.1	*18.6*	16.2
42	15.3	*12.6*	11.9	*10.0*	8.7
43	1.6	*0.4*	6.7	*5.8*	3.1
TOTAL	***698.8***	*573.4*	***560.9***	***476.1***	***410.5***
% of direct emissions from TOTAL, average	**-**	*82*	**-**	*85*	**-**

Car has the primary share in the total amount of the GHG emissions from travel to/from airport in the UK at over 85% (Figure 7.10). Taxi is in the second position (8%), due to a single long-haul taxi journey from Bournemouth to Stansted (respondent code 9) which alone had produced 81% of the GHG emissions attributed to taxi rides. If this journey is excluded, travel by coach generates the second largest quantity of GHG emissions, with the share of about 3%. The contribution from train journeys is negligible in the case of Ecoinvent (<1% of the total). It is higher for the methods by Gössling *et al.* (2005) and DEFRA, i.e. 2-2.5%. The reason is the difference in carbon intensity coefficients employed by the reviewed methods for transportation by train (see 7.2.1.3). The share of train journeys in the total GHG emissions from the survey sample is low despite the lengthy distances (over 100 km return) covered. The same distance travelled by car would have produced a 5 times larger carbon footprint for Ecoinvent and 2 times larger carbon footprint for the method by Gössling *et al.* (2005). This identifies switching to train as a major carbon footprint mitigation policy for transportation to/from airport as an element of holiday travel.

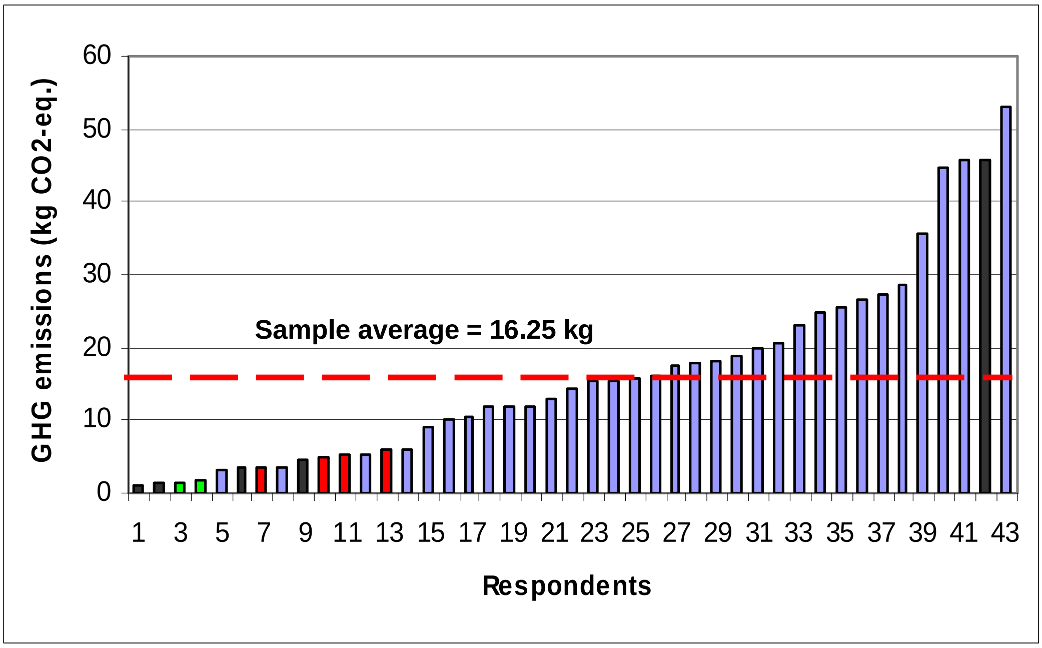
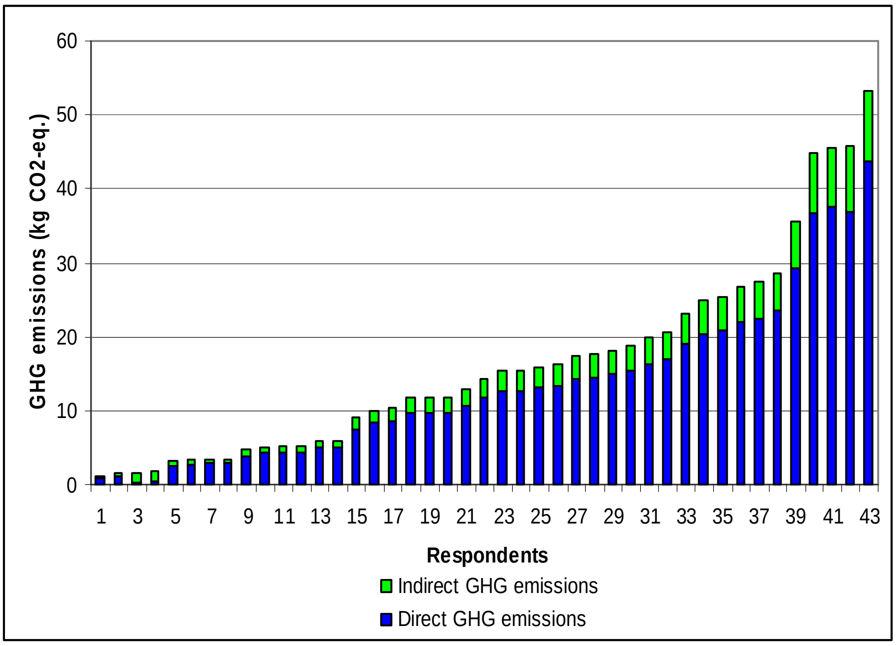


Figure 7.10. GHG emissions from the survey sample related to travel to/from airport in the UK (example of estimates, Ecoinvent). Source: Author.

Blue colour represents journeys made by car, black colours stands for taxi rides. Light green colour indicates travel by train, red colour – journeys made by coach.

The estimates by Ecoinvent and DEFRA suggest that the 'indirect' GHG emissions from travel to/from airport in the UK are significant and may have the average contribution of 18% and 15%, respectively, to the total carbon footprint from this element of the holiday package in the Algarve (Figure 7.11). This finding is in a fairly good agreement with Frischknecht *et al.* (2007a) who found that the share of the 'indirect' energy and carbon requirements for passenger transport may equate, on the average, to 16%.

Ecoinvent



DEFRA

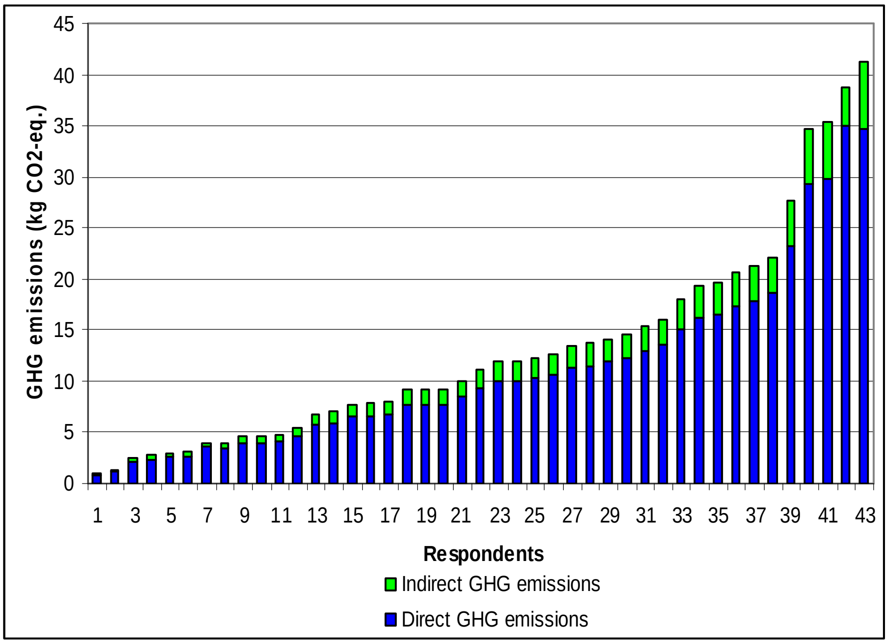


Figure 7.11. Direct versus 'indirect' GHG emissions related to travel to/from airport in the UK.

Blue colour represents the direct GHG emissions; green colour corresponds to the 'indirect' carbon footprint.

The estimates from Ecoinvent suggest that the most noticeable contribution of the 'indirect' GHG emissions is typical for train travel where it is responsible for up to 70% of the total carbon footprint. This is due to the relatively small amounts of the GHG emissions arisen from regional train operations and significant amounts of the embodied energy and related carbon footprint attributable to the manufacture and maintenance of trains and railway infrastructure.

The estimates of the GHG emissions from airport travel in the Algarve are presented in Table 7.9. This carbon footprint is identical for all survey respondents as airport transfers organised by TUI Travel are usually made by coaches of the same or similar capacities and via the same itinerary.

Table 7.9. GHG emissions from travel to/from airport in the Algarve.

Kg CO_2-eq. or kg CO_2 per passenger. Return distance is 66.4 km (Google Maps 2011).

GHG emissions / Method	Ecoinvent	DEFRA	Gössling *et al.* (2005)
Total	2	1.8	1.4
Direct only	1.7 (85%)	1.5 (83%)	N/A

7.2.3 GHG emissions from air travel

Air transport is recognized as an element of holiday travel producing the largest share of its carbon footprint. To estimate the contribution of air travel to the total GHG emissions from the holiday package in the Algarve and to compare this carbon footprint against the carbon share attributed to other holiday travel elements, the carbon intensity coefficients for air transport are required. The review of methods for carbon impact appraisal of tourism has revealed that their GHG emission coefficients for air travel are based on different background assumptions. Hence, and similar to the carbon intensity factors for other transport modes, the original carbon intensity coefficients had to be amended (modified) in order to model air transport within the case study under review with a higher degree of accuracy and with a better approximation to the reality. The modification procedure is as follows:

Ecoinvent is capable of estimating the GHG emissions from three categories of air passenger transport (Table 7.10). The Algarve is a short-haul European destination which is situated 1687 km away from the UK (Air Routing International 2011). Hence, the category of 'Long-haul intra-continental' flights is automatically not suitable for analysis. The category of 'Short-haul intra-European' flights was therefore considered for carbon impact appraisal. However, a closer analysis has shown that this category of air transport is based on assumptions which are not representative of the modeled reality.

Table 7.10. Categories of air passenger transport addressed by Ecoinvent.

Source: Adapted from Doka 2009; Spielmann et al. (2003); Spielmann et al. (2004).

Background assumptions	**Short-haul intra-European**	**Long-hail intra-continental**	**Average air transport**
One-way flying distance	500	6000	4356
Maximum load (seats)	100	400	325
Occupancy (seats or %)	65 or 65%	320 or 80%	256 or 78%
GHG emissions factor, pkm	0.197	0.108	0.154

First, Ecoinvent follows the North-American tradition and defines short-haul flying distances as those within the range of up to 500 km. These are often referred to as 'regional' flights and 'extremely short-haul' destinations in Europe (see 5.2.1). Such short distances are usually serviced by the older and smaller aircraft which generate a substantial carbon footprint per pkm. This is due to the significant fuel consumption during the take-off and landing stages of the flight, low maximum loading and lower occupancies (Chapman 2007; Gössling 2000).

Second, the short-haul fleet of TUI Travel airlines predominantly consists of Airbus 320 and Boeing 737 series aircrafts (First Choice 2010; Thomson Airways 2010). These aircrafts have a maximum seating capacity of 140-160 (DEFRA 2010b; Koroneos *et al.* 2005) which is circa 50% larger than the maximum capacity of 100 assumed by Ecoinvent for short-haul intra-European flights (Table 7.10). This means that, when the GHG emissions are calculated on a per 'passenger km' basis, the real TUI Travel flights will be less carbon intense than those modeled by Ecoinvent, if the 'Short-haul intra-European' aircraft category is applied.

Third, the average occupancy factors of charter flights organised by TUI Travel to/from Faro is higher than the average occupancy of regular scheduled flights assumed by Ecoinvent. For example, the average occupancy of the TUI Travel holiday fleet was reported as exceeding 80% in 2009 (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010).[18] This is because of a lower frequency of charter services and their operation on demand.

[18] A more precise number on aircraft occupancy was not disclosed for the purpose of confidentiality.

Hence, the average flight occupancy of 65% suggested by Ecoinvent (Table 7.10) is deemed to be inappropriate for the case study under review and needs to be amended (increased) to represent the 'real-life' situation.

To conclude, given these significant limitations of the assumptions related to the 'Short-haul intra-European' flight category, it is argued that the 'Average air transport' category of passenger aircrafts in the Ecoinvent database suits the analysis better. It is acknowledged that the background assumptions used here also suffer from shortcomings, namely: 1) the proposed flying distance in this category is more appropriate for medium-haul rather than short-haul flights; 2) the assumed maximum load factor is higher than the maximum load factors for the Airbus 320 and Boeing 737 series aircrafts and 3) the suggested occupancy factor is still low compared to the high occupancies of charter flights. Despite these limitations, the employment of the 'Average air transport' category is deemed to be more appropriate in this case study. Since no further categories of air passenger transport can be assessed by Ecoinvent, the figures from the 'Average air transport' flights were used for carbon impact appraisal of travel to/from the destination within the holiday package in the Algarve. A sensitivity analysis is conducted in section 8.2 to demonstrate how the carbon footprint assessment results change, should the 'Short-haul intra-European category of flights from Ecoinvent be applied for analysis.

The method by Gössling *et al.* (2005) distinguishes between intra-EU and inter-continental flights. The occupancy factor of 70% is used for the former category. It is however unclear how this figure can be translated into the 'number of seats occupied' as the method does not specify the maximum aircraft capacity. The background information on flying distances is also absent. The GHG emission factor for intra-EU flights from Gössling *et al.* (2005) was therefore used for analysis with no further changes applied. This is because any adjustments are hardly possible due to the absence of the required supporting information.

Importantly, the method by Gössling *et al.* (2005) applies a radiative forcing (RF) coefficient of 2.7 to all its estimates of air transport. This is in order to account for a heavier damage inflicted by the GHG emissions at cruising altitudes. In addition, a detour factor of 1.05 is employed to address the deviations from the 'straight line' travel distances and to account for the related extra carbon footprints. While the necessity to apply a detour factor for estimates of the carbon footprint from air transport is indisputable, the default application of a radiative forcing coefficient is questioned. This is because the science behind the RF effect is uncertain (Berners-Lee *et al.* 2011); as a result, there is no agreement in the literature with regard to the magnitude of a RF factor whose values vary from 1 to 4.7, depending on the source of estimate (Grassl and Brockhagen 2007). The RF of 2.7 is suggested, for example, by IPCC (Jardine 2005; Penner *et al.* 1999) while the RF of 1.9 is used by many carbon calculators. At the same time, some experts stress that the RF multipliers should be applied with caution as they may lead to significant overestimations of the GHG emissions from air travel (see, for instance, Foster *et al.* 2006). This particularly applies to regional and some short-haul flights as it is claimed that they do not reach higher altitudes where the GHG emissions cause the RF effect. It is therefore argued that a RF coefficient should not be used by default, but rather utilised for a sensitivity analysis, should the carbon impact appraisal of holiday activities which involve air travel be conducted. Thus, the GHG emission factors for air passenger transport from Gössling *et al.* (2005) were adjusted to exclude a RF multiplier. The original factors (with an embedded multiplier) are applied for a sensitivity analysis in section 8.2, to demonstrate its effect on the carbon footprint assessment results.

Importantly, as for other methods, Ecoinvent does not employ any RF multipliers, i.e. its RF is equal to 1 (Frischknecht *et al.* 2007b; Goedkoop *et al.* 2008) while DEFRA suggests, but does not use, a RF factor of 1.9. The exclusion of radiative forcing by these methods is due to scientific uncertainties about the magnitude of this effect (Brakkee *et al.* 2008; DEFRA 2010b). Notably, DEFRA also applies the uplift (detour) factor of 1.09 to its estimates; this is in order to account for non-direct routes made by aircraft (DEFRA 2010b). Like in the case of the method by Gössling *et al.* (2005), a RF factor was not included into the estimates of the GHG emissions produced by DEFRA while the detour coefficient was retained.

The GHG emission factors from Ecoinvent also account for the additional carbon footprint related to the aircraft detours and turning loops (Spielmann *et al.* 2004). The supporting literature does not however specify its magnitude; hence, the GHG emission coefficients from Ecoinvent were not modified to account for possible inter-methodological variations in the detour factors.

The method by DEFRA distinguishes between domestic, short-haul international and long-haul international flights. It further classifies international flights on the basis of the cabin class. For this case study the 'short-haul international economy class category' was used. It assumes the average maximum capacity (load factor) of 176 seats and the average occupancy factor of 82.4% for short-haul passenger flights. This equates, on the average, to 145 passengers per aircraft (DEFRA 2010b). While the assumption of the average maximum capacity can be a slight overestimation for the Airbus 320 and Boeing 737 series aircrafts considered here (which has implications for the carbon footprint of the reviewed flights which will, in this case, be slightly underestimated if calculated on a pkm basis), the average occupancy factor is deemed to be appropriate. Hence, it is argued that, if compared to other methods, the assumptions from DEFRA are more suitable for the case study under review, and its GHG emission coefficients for air travel represent the modeled reality with the greatest approximation. Table 7.11 summarizes the method-specific GHG emission factors for air passenger transport which were employed for carbon impact appraisal of the holiday package in the Algarve.

Table 7.11. GHG emission factors for air travel.

Transport mode / Method	**Ecoinvent**	**DEFRA, economy class**	**Gössling *et al.* (2005)**
	kg CO_2-eq.		**kg CO_2**
Total GHG emissons, pkm	0.154	0.11	0.3969
Operational (direct) GHG emissions, pkm	*0.124*	*0.093*	*0.3969*
'Indirect' GHG emissions, pkm	*0.03*	*0.017*	*N/A*
RF coefficient	*1*	*1*	*2.7*
uplift factor	*Unknown, arguably 1*	*1.09*	*1.05*
adjusted RF coefficient	*1*	*1*	*1*
Adjusted GHG emission coefficient, total	***0.154***	***0.12***	***0.147***

Table 7.12 provides estimates of the GHG emissions related to air transportation of survey respondents from different UK airports to/from the Algarve, as suggested by different methods. Estimates are on return distances and based on the data from Table 6.4 and 7.11.

The analysis shows that the maximum carbon footprint is attributed to air travel from Glasgow as this airport is situated at the longest distance from Faro International Airport. The minimum amounts of GHG emissions are produced by tourists travelling from Cardiff and Bristol. If the total carbon footprint is calculated for the whole survey sample, the values of 23.3 tonnes (4.6 tonnes or 18% 'indirect' GHG emissions), 18.2 tonnes (4.1 tonnes or 22% 'indirect') and 22.2 tonnes are suggested by Ecoinvent, DEFRA and Gössling *et al.* (2005) methods, respectively. The average amounts of GHG emissions per survey respondent are estimated by these methods as 542 kg (106 kg 'indirect' GHG emissions) for Ecoinvent, 423 kg (95 kg 'indirect') for DEFRA, and 517 kg for Gössling *et al.* (2005), respectively.

Table 7.12. GHG emissions from air travel, UK – the Algarve – UK, as suggested by different assessment methods.

UK airport	GHG emissions (kg CO_2-eq. or kg of CO_2)				
	Ecoinvent		***DEFRA***		***Gössling et al. (2005)***
	Total	*Direct only'*	Total	*Direct only'*	
Belfast	605	*487*	474	*367*	578
Birmingham	549	*442*	430	*333*	524
Bristol	508	*409*	398	*308*	485
Cardiff	505	*407*	395	*306*	482
Doncaster-Sheffield	587	*473*	460	*356*	561
Gatwick	520	*418*	407	*315*	496
Glasgow	651	*524*	509	*395*	621
Manchester	575	*463*	450	*349*	549
Newcastle	634	*511*	496	*385*	605
Stansted	546	*440*	428	*331*	522

A comparative analysis indicates that Ecoinvent suggests the highest estimates of the total carbon footprint related to air transport. On average, they are circa 30% and 5% larger than the figures from DEFRA and Gössling *et al.* (2005), respectively. The higher estimates from Ecoinvent compared to DEFRA are partially due to the issue with selection of the most representative carbon intensity coefficient for short-haul flights.

If only the direct carbon footprint is estimated, the numbers from Ecoinvent and DEFRA are significantly lower than those proposed by Gössling *et al.* (2005), i.e. by 15% and 35% respectively. This can be partially explained by the dated and global averaged carbon intensity coefficients employed by the method by Gössling *et al.* (2005).

As for the share of the 'indirect' GHG emissions in the total carbon footprint from air travel, both Ecoinvent and DEFRA report the contribution of about 20%. Importantly, these 'indirect' GHG emissions stem from different sources: while 20% of the 'indirect' carbon footprint estimated by DEFRA is attributed to the fuel chain, the 20% from Ecoinvent also comes from the capital goods and infrastructure (i.e. aircraft and airport). Since the GHG emission factors from DEFRA are more appropriate for the case study under review, it is argued that the most comprehensive estimates of the *total* GHG emissions would be obtained by summing up the 'indirect' share from the capital goods and infrastructure as suggested by Ecoinvent with the total amount of the carbon footprint estimated by DEFRA. The resultant estimates will take into account the *maximum* range of the 'indirect' carbon impacts from transport.

7.2.4 GHG emissions from hotel stay

To estimate the GHG emissions from staying at HV Algarve, the carbon intensity coefficients for electricity and LPG consumption are required (Table 7.13).

Table 7.13. Carbon intensity coefficients and GHG emission estimates from staying at HV Algarve, as suggested by different methods.

Energy type	**Ecoinvent**	**DEFRA**	**Gössling *et al.* (2005)**
	kg CO_2-eq.		**kg CO_2**
Electricity, 1 kWh	0.6	0.56	0.57
where direct only	*0.59 (98%)*	*0.5 (89%)*	*N/A*
Per '1 guest night' = 13 kWh	**7.8**	**7.3**	**7.4**
where direct only	*7.7*	*6.5*	*N/A*
LPG, 1 kWh	0.25	0.26	0.57
where direct only	*0.23 (92%)*	*0.23 (88%)*	*N/A*
Per '1 guest night' = 3.5 kWh	**0.9**	**0.9**	**2**
where direct only	*0.8*	*0.8*	*N/A*
TOTAL	**8.7**	**8.2**	**9.4**
where direct only	*8.5 (98%)*	*7.3 (89%)*	*N/A*

Table 7.13 needs some clarification. As for electricity use in hotels, the method by Gössling *et al.* (2005) applies the GHG emission factor from Schafer and Victor (1999) which is based on the world average electricity generation mix. It does not account for any 'indirect' carbon footprint and represents the year of 1990. Given that more advanced and carbon efficient technologies are now employed for energy production, the GHG emission factor from Gössling *et al.* (2005) may not be accurate enough. Reliance on the global average value with no regional and/or national differentiation in carbon intensities of energy generation is another limitation of this method.

In contrast, Ecoinvent is capable of addressing the country-specific situation as it provides the estimates of GHG emissions for electricity mix in Portugal. These include the carbon footprint from domestic electricity production and the GHG emissions associated with imported electricity produced in other countries. Given that the Algarve region borders on Spain (Google Maps 2011) and may therefore fulfill some of its electricity demand via the imports of Spanish electricity, the employment of this GHG emission factor is justified. Ecoinvent differentiates between the direct and 'indirect' carbon footprints. While the former arises from the combustion of fuel used for electricity generation and includes the lifecycle emissions from the whole fuel chain, the latter stands for the GHG emissions related to the manufacture of energy infrastructure and capital goods production. Importantly, neither category of carbon footprint includes additional GHG emissions arisen from energy losses in transmission and distribution

(Spielmann *et al.* 2004). This implies that Ecoinvent accounts only for the GHG emissions from electricity *generated, not consumed*. The amounts of the electricity lost in transmission and distribution can however be large and may alter the final picture of the total carbon footprint from electricity use.

In contrast, DEFRA provides the estimates of GHG emissions which include transmission and distribution losses (DEFRA 2010a), i.e. they are specially designed to appraise the carbon footprint from the final electricity user. The 'indirect' GHG emissions addressed by DEFRA account for extraction, transport, production and distribution of fuels; they do not however handle the 'indirect' carbon footprint from the manufacture of energy infrastructure and capital goods. Another limitation is that the GHG emission factor from DEFRA represents the 'combined electricity and heat generation' in Portugal, i.e. it does not separate the carbon footprints from electricity and heat production. It is valid for the year of 2006 but makes its estimate on the basis of the 5-year rolling average values to account for the inter-seasonal variations in carbon intensities of fuels (DEFRA 2010a).

Having analysed the underlying assumptions employed by the reviewed methods for carbon footprint assessment of electricity use, it is argued that the most holistic estimate would be the sum of the DEFRA's 'consumed' electricity (accounting for transmission and distribution losses and covering the fuel chain-related 'indirect' GHG emissions) and the Ecoinvent's 'indirect' 'capital goods and infrastructure'-related carbon footprints. Given that the GHG emissions from the transmission and distribution losses are likely to be more significant than the GHG emissions from energy infrastructure and capital goods production, it is further argued that, in terms of accuracy, the electricity carbon footprint estimates from DEFRA are more appropriate for the case study under review than the GHG emission factors for electricity from Ecoinvent and Gössling *et al.* (2005).

As for LPG use, Gössling *et al.* (2005) do not provide an estimate of the carbon footprint from this type of fuel. This is because this method is not fuel-specific and measures all energy-related GHG emissions on the basis of the global average carbon intensity coefficients for electricity generation mix, regardless of the fuel type used for energy generation. Hence, LPG use in HV Algarve will be measured by this method with the help of the GHG emission factor attributable to electricity production.

Similar to the method by Gössling *et al.* (2005), there are no life cycle inventory data on LPG in the Ecoinvent database (Atlantic Consulting 2009; Boureima *et al.* 2009). The required GHG emission coefficients for LPG were therefore collected from the LCA-based studies carried out by independent researchers (Atlantic Consulting 2009; Johnson 2009). These measure both direct and 'indirect' carbon intensities of LPG, where the latter accounts for the GHG emissions from the manufacture of energy producing infrastructure and production of capital goods. The GHG emission factor retrieved from the literature is UK-specific.

DEFRA does not provide the GHG emission factor for heating with LPG in Portugal. Instead, and similar to Ecoinvent, it measures the carbon intensity of LPG as a general fuel for energy generation in the UK. It is assumed that no significant discrepancy exists in the carbon intensity of LPG within Europe; hence, the UK-specific values are employed in this study. These are based on the 'net' calorific value which represents the 'real world' conditions, i.e. LPG combustion in a boiler plant (DEFRA 2010a). Importantly, and similar to the electricity case described above, the 'indirect' GHG emissions from LPG use are classified by DEFRA as those arising from extraction, transport, production and distribution of fuels. These do not account for the additional 'indirect' carbon footprint stemming from the energy infrastructure and capital goods.

Table 7.13 shows that the GHG emission factors for LPG proposed by Ecoinvent and DEFRA are almost identical, although the former covers more dimensions of the 'indirect' GHG emissions. It is argued that these two methods provide the most accurate carbon footprint estimates for LPG consumption in the case study under review. This is because the GHG emission factor from Gössling *et al.* (2005) is dated and does not differentiate between fuel types. To enhance the comprehensiveness of future estimates it is recommended that the DEFRA method is supplemented with the data on the 'indirect' carbon footprint from energy infrastructure and capital goods production, as assessed by Ecoinvent.

The analysis also indicates that, compared to Ecoinvent and DEFRA, the method by Gössling *et al.* (2005) is accurate enough to produce reliable estimates of GHG emissions from electricity consumption in Portugal. This is because the global average carbon intensity coefficient for electricity use employed by this method is likely to be very similar to the Portugal and/or EU-specific ones. In contrast, the measurements of the carbon footprint from LPG consumption are overestimated by the method by Gössling *et al.* (2005) due to the reasons outlined above. The fundamental limitation of this method is its incapability to estimate the 'indirect' carbon footprint. DEFRA (Table 7.13) has demonstrated that its magnitude can be noticeable (>10%) and should not therefore be ignored in carbon footprint analysis.

To summarise, DEFRA and, to a slightly lesser extent, Ecoinvent are deemed to provide the most accurate estimates of the GHG emissions from the hotel stay. A hybrid method that would be capable of measuring all dimensions of the 'indirect' carbon footprint at once might represent the most holistic approach to carbon footprint assessments in tourism. This study aims to show how such a hybrid method can be developed on the basis of the Ecoinvent and DEFRA methods (see 7.3.1).

If the estimates of the GHG emissions from hotel stay obtained in this review are compared against the results of carbon footprint assessment for hotels reported in other studies, the analysis shows that HV Algarve is less carbon-intense than many hotels from the literature (Table 4.3). This is because it is a modern build constructed according to the latest insulation technologies and since its operations are limited in winter. If the hotel under review had been older and, consequently, less energy-efficient and if it had operated on a traditional 'full season' basis, it is deemed that it would have generated larger amounts of GHG emissions per 'guest night'.

7.3. ASSESSING THE TOTAL GHG EMISSIONS FROM THE HOLIDAY PACKAGE

To estimate the total carbon footprint produced by the survey respondents, the GHG emissions from its all specific elements need to be summed. Table 7.14 illustrates the aggregate estimates of the GHG emissions from the holiday package as suggested by different methods.

If the total carbon footprint from the survey sample is measured, the analysis shows that the largest estimates are produced by the Ecoinvent and Gössling *et al.* (2005) methods while the figures proposed by DEFRA are more modest (Figure 7.12). The largest discrepancy is found in the estimates of the GHG emissions from air transport while the differences in estimates of other holiday travel elements are less significant. The dated GHG emission factors utilised by Gössling *et al.* (2005) and the methodological issues related to the carbon footprint assessment of air travel attributable to Ecoinvent are deemed to be the primary reasons for inconsistencies. Moreover, the estimates from Ecoinvent and DEFRA include both direct and 'indirect' GHG emissions while the figures from Gössling *et al.* (2005) represent the direct GHG emissions only. If the 'direct only' GHG emissions are considered, the method by Gössling *et al.* (2005) suggests the largest estimates.

Table 7.14. Individual and total GHG emissions from the holiday package in the Algarve (in kg of CO_2-eq. or kg of CO_2), aggregate data.

№	Method	Transport element						Non-transport element		Mixed element		TOTAL	
		Origin country component		Transit component		Destination-based components							
		Travel to/from airport in the UK		**Air travel, UK - Faro**		**Travel to/from airport in the Algarve**		**Hotel stay in the Algarve**		**Tourist activities in the Algarve**			
		Total	*Direct only*	**Total**	*Direct only*	**Total**	*Direct only*	**Total**	*Direct only*	**Total**	*Direct only*	**ALL**	*Direct only*
1	Ecoinvent	**16.2**	*13.3*	**519.6**	*418.4*	**2**	*1.7*	**87**	*85*	**16.2**	*11*	**636.4**	*529.4 (83%)*
	DEFRA	**12.6**	*10.6*	**406.6**	*315*	**1.8**	*1.5*	**82**	*73*	**15.1**	*13.5*	**518.1**	*413.6 (80%)*
	Gössling *et al.* (2005)	**9.2**		**496**		**1.4**		**94**		**10.8**		**611.4**	
2	Ecoinvent	**19.8**	*16.3*	**575.5**	*463.4*	**2**	*1.7*	**121.8**	*119*	**15.5**	*14.4*	**734.6**	*614.8 (84%)*
	DEFRA	**15.4**	*13*	**450.3**	*348.9*	**1.8**	*1.5*	**114.8**	*102.2*	**18.6**	*16.8*	**600.9**	*482.4 (80%)*
	Gössling *et al.* (2005)	**11.3**		**549.3**		**1.4**		**131.6**		**13.8**		**707.4**	
3	Ecoinvent	**26.6**	*21.9*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**2.6**	*2.6*	**611.7**	*504.1 (82%)*
	DEFRA	**20.6**	*17.4*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**2.6**	*2.6*	**489**	*387.6 (79%)*
	Gössling *et al.* (2005)	**15.2**		**496**		**1.4**		**65.8**		**2.6**		**581**	
4	Ecoinvent	**1.8**	*0.4*	**519.6**	*418.4*	**2**	*1.7*	**87**	*85*	**26.8**	*26.4*	**637.2**	*531.9 (83%)*
	DEFRA	**7.6**	*6.6*	**406.6**	*315*	**1.8**	*1.5*	**82**	*73*	**29.3**	*28.2*	**527.3**	*424.3 (80%)*
	Gössling *et al.* (2005)	**3.5**		**496**		**1.4**		**94**		**26.2**		**621.1**	
5	Ecoinvent	**3.4**	*2.8*	**575.5**	*463.4*	**2**	*1.7*	**121.8**	*119*	**48.7**	*44.4*	**751.4**	*631.3 (84%)*
	DEFRA	**2.9**	*2.6*	**450.3**	*348.9*	**1.8**	*1.5*	**114.8**	*102.2*	**43.5**	*40.6*	**613.3**	*495.8 (81%)*
	Gössling *et al.* (2005)	**2.2**		**549.3**		**1.4**		**131.6**		**38.5**		**723**	
6	Ecoinvent	**11.7**	*9.6*	**519.6**	*418.4*	**2**	*1.7*	**95.7**	*93.5*	**17.8**	*15.3*	**646.8**	*538.5 (83%)*
	DEFRA	**9.1**	*7.7*	**406.6**	*315*	**1.8**	*1.5*	**90.2**	*80.3*	**14.6**	*12.9*	**522.3**	*417.4 (80%)*
	Gössling *et al.* (2005)	**6.7**		**496**		**1.4**		**103.4**		**11.7**		**619.2**	
7	Ecoinvent	**1.5**	*1.2*	**549.3**	*442.3*	**2**	*1.7*	**121.8**	*119*	**16.7**	*15.6*	**691.3**	*579.8 (84%)*
	DEFRA	**1.3**	*1.1*	**429.8**	*333*	**1.8**	*1.5*	**114.8**	*102.2*	**23**	*20.2*	**570.7**	*458 (80%)*
	Gössling *et al.* (2005)	**1**		**524.3**		**1.4**		**131.6**		**15.2**		**673.5**	
8	Ecoinvent	**11.7**	*9.6*	**519.6**	*418.4*	**2**	*1.7*	**87**	*85*	**-**		**620.3**	*514.7 (83%)*
	DEFRA	**9.1**	*7.7*	**406.6**	*315*	**1.8**	*1.5*	**82**	*73*	**-**		**499.5**	*397.2 (80%)*
	Gössling *et al.* (2005)	**6.7**		**496**		**1.4**		**94**		**-**		**598.1**	
9	Ecoinvent	**45.8**	*37.4*	**546.4**	*440*	**2**	*1.7*	**60.9**	*59.5*	**-**		**655.1**	*538.6 (82%)*
	DEFRA	**38.8**	*35*	**427.5**	*331.2*	**1.8**	*1.5*	**57.4**	*51.1*	**-**		**525.5**	*418.8 (80%)*
	Gössling *et al.* (2005)	**29.6**		**521.6**		**1.4**		**65.8**		**-**		**618.4**	
10	Ecoinvent	**3.5**	*2.9*	**508**	*409*	**2**	*1.7*	**121.8**	*119*	**33.3**	*29.7*	**668.6**	*562.3 (84%)*
	DEFRA	**2.7**	*2.3*	**397.5**	*308*	**1.8**	*1.5*	**114.8**	*102.2*	**32.9**	*28.3*	**549.7**	*442.3 (80%)*
	Gössling *et al.* (2005)	**2**		**485**		**1.4**		**131.6**		**25.7**		**645.7**	
11	Ecoinvent	**9.1**	*7.5*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**7.6**	*7*	**599.2**	*494.1 (82%)*
	DEFRA	**7**	*5.9*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**8.9**	*8*	**481.7**	*381.5 (79%)*
	Gössling *et al.* (2005)	**5.2**		**496**		**1.4**		**65.8**		**6.6**		**575**	

12	Ecoinvent	**17.4**	*14.3*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**1.8**	*1.5*	**601.7**	*495.4 (82%)*
	DEFRA	**13.5**	*11.4*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**1.6**	*1.5*	**480.9**	*380.5 (79%)*
	Gössling *et al.* (2005)	**9.9**		**496**		**1.4**		**65.8**		**1.3**		**574.4**	
13	Ecoinvent	**45.6**	*37.5*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**5.6**	*5.2*	**633.7**	*522.3 (82%)*
	DEFRA	**35.3**	*29.8*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**5.3**	*5.1*	**506.4**	*402.5 (79%)*
	Gössling *et al.* (2005)	**26**		**496**		**1.4**		**65.8**		**4.9**		**594.1**	
14	Ecoinvent	**17.6**	*14.5*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**2.3**	*2.2*	**602.4**	*496.3 (82%)*
	DEFRA	**13.7**	*11.5*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**2.8**	*2.6*	**482.3**	*381.7 (79%)*
	Gössling *et al.* (2005)	**10**		**496**		**1.4**		**65.8**		**2.2**		**575.4**	
15	Ecoinvent	**12.9**	*10.6*	**519.6**	*418.4*	**2**	*1.7*	**121.8**	*119*	**22.2**	*20.6*	**678.5**	*570.3 (84%)*
	DEFRA	**10**	*8.4*	**406.6**	*315*	**1.8**	*1.5*	**114.8**	*102.2*	**29.8**	*26.1*	**562.9**	*453.2 (81%)*
	Gössling *et al.* (2005)	**7.4**		**496**		**1.4**		**131.6**		**19.8**		**656.2**	
16	Ecoinvent	**4.9**	*4.3*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**3**	*2.6*	**590.4**	*486.5 (82%)*
	DEFRA	**4.6**	*3.8*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**2.7**	*2.5*	**473.1**	*373.9 (79%)*
	Gössling *et al.* (2005)	**3.6**		**496**		**1.4**		**65.8**		**2.3**		**569.1**	
17	Ecoinvent	**27.4**	*22.5*	**519.6**	*418.4*	**2**	*1.7*	**121.8**	*119*	**57.5**	*49.1*	**728.3**	*610.7 (84%)*
	DEFRA	**21.2**	*17.9*	**406.6**	*315*	**1.8**	*1.5*	**114.8**	*102.2*	**49**	*42.9*	**593.4**	*479.5 (81%)*
	Gössling *et al.* (2005)	**15.6**		**496**		**1.4**		**131.6**		**37.8**		**682.4**	
18	Ecoinvent	**25.3**	*20.8*	**519.6**	*418.4*	**2**	*1.7*	**121.8**	*119*	**27.4**	*24.7*	**696.1**	*584.6 (84%)*
	DEFRA	**19.7**	*16.6*	**406.6**	*315*	**1.8**	*1.5*	**114.8**	*102.2*	**30.9**	*26.7*	**573.8**	*462 (81%)*
	Gössling *et al.* (2005)	**14.4**		**496**		**1.4**		**131.6**		**22.2**		**665.6**	
19	Ecoinvent	**14.3**	*11.8*	**519.6**	*418.4*	**2**	*1.7*	**121.8**	*119*	**37.5**	*31.4*	**695.2**	*582.3 (84%)*
	DEFRA	**11.1**	*9.4*	**406.6**	*315*	**1.8**	*1.5*	**114.8**	*102.2*	**30**	*26*	**564.3**	*454.1 (80%)*
	Gössling *et al.* (2005)	**8.2**		**496**		**1.4**		**131.6**		**23**		**660.2**	
20	Ecoinvent	**35.6**	*29.3*	**519.6**	*418.4*	**2**	*1.7*	**121.8**	*119*	**21.4**	*20.8*	**700.4**	*589.2 (84%)*
	DEFRA	**27.6**	*23.3*	**406.6**	*315*	**1.8**	*1.5*	**114.8**	*102.2*	**21.3**	*20.9*	**572.1**	*462.9 (81%)*
	Gössling *et al.* (2005)	**20.3**		**496**		**1.4**		**131.6**		**20.4**		**669.7**	
21	Ecoinvent	**1.1**	*0.9*	**634.2**	*510.8*	**2**	*1.7*	**121.8**	*119*	**50.7**	*49.5*	**809.8**	*681.9 (84%)*
	DEFRA	**1**	*0.9*	**496.3**	*384.5*	**1.8**	*1.5*	**114.8**	*102.2*	**53.3**	*51.6*	**667.2**	*540.7 (81%)*
	Gössling *et al.* (2005)	**0.7**		**605.5**		**1.4**		**131.6**		**48.8**		**788**	
22	Ecoinvent	**4.7**	*3.8*	**549.3**	*442.3*	**2**	*1.7*	**121.8**	*119*	**5.2**	*4.9*	**683**	*571.7 (84%)*
	DEFRA	**4**	*3.6*	**429.8**	*333*	**1.8**	*1.5*	**114.8**	*102.2*	**7.2**	*6.3*	**557.6**	*446.6 (80%)*
	Gössling *et al.* (2005)	**3**		**524.3**		**1.4**		**131.6**		**4.7**		**665**	
23	Ecoinvent	**23.1**	*19*	**508**	*409*	**2**	*1.7*	**60.9**	*59.5*	**8.7**	*8.1*	**602.7**	*497.3 (82%)*
	DEFRA	**17.9**	*15.1*	**397.5**	*308*	**1.8**	*1.5*	**57.4**	*51.1*	**8.2**	*7.9*	**482.8**	*383.6 (79%)*
	Gössling *et al.* (2005)	**13.2**		**485**		**1.4**		**65.8**		**7.5**		**572.9**	
24	Ecoinvent	**24.8**	*20.4*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**-**		**607.3**	*500 (82%)*
	DEFRA	**19.2**	*16.2*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**-**		**485**	*383.8 (79%)*
	Gössling *et al.* (2005)	**14.1**		**496**		**1.4**		**65.8**		**-**		**577.3**	
25	Ecoinvent	**15.8**	*13*	**505**	*406.6*	**2**	*1.7*	**95.7**	*93.5*	**9.8**	*9.1*	**628.3**	*523.9 (83%)*

	DEFRA	12.3	10.4	395.1	306.1	1.8	1.5	90.2	80.3	13.2	11.6	512.6	409.9 (80%)
	Gössling *et al.* (2005)	9		482		1.4		103.4		8.7		604.5	
26	Ecoinvent	11.8	9.7	575.5	463.4	2	1.7	121.8	119	-		711.1	593.8 (83%)
	DEFRA	9.1	7.7	450.3	348.9	1.8	1.5	114.8	102.2	-		576	460.3 (80%)
	Gössling *et al.* (2005)	6.7		549.3		1.4		131.6		-		689	
27	Ecoinvent	10.1	8.3	549.3	442.3	2	1.7	121.8	119	40.4	40	723.6	611.3 (84%)
	DEFRA	7.8	6.6	429.8	333	1.8	1.5	114.8	102.2	40.1	40	594.3	483.3 (81%)
	Gössling *et al.* (2005)	5.7		524.3		1.4		131.6		39.7		702.7	
28	Ecoinvent	10.4	8.5	587.4	472.9	2	1.7	121.8	119	25.5	24.9	747.1	627 (84%)
	DEFRA	8	6.8	459.6	356.1	1.8	1.5	114.8	102.2	27.1	26.1	611.3	492.7 (81%)
	Gössling *et al.* (2005)	5.9		560.7		1.4		131.6		24.5		724.1	
29	Ecoinvent	15.4	12.6	575.5	463.4	2	1.7	121.8	119	15	14	729.7	610.7 (84%)
	DEFRA	11.9	10	450.3	348.9	1.8	1.5	114.8	102.2	18.4	16.6	597.2	479.2 (80%)
	Gössling *et al.* (2005)	8.8		549.3		1.4		131.6		13.5		704.6	
30	Ecoinvent	18.2	14.9	650.8	524	2	1.7	121.8	119	9.4	8.8	802.2	668.4 (83%)
	DEFRA	14.1	11.9	509.2	394.5	1.8	1.5	114.8	102.2	10.6	9.8	650.5	519.9 (80%)
	Gössling *et al.* (2005)	10.4		621.2		1.4		131.6		8.4		773	
31	Ecoinvent	5.1	4.2	605.4	487.4	2	1.7	60.9	59.5	13.4	12.4	686.8	565.2 (82%)
	DEFRA	4	3.4	473.7	367	1.8	1.5	57.4	51.1	12.6	12.1	549.5	435.1 (79%)
	Gössling *et al.* (2005)	2.9		577.9		1.4		65.8		11.4		659.4	
32	Ecoinvent	20.7	17	519.6	418.4	2	1.7	60.9	59.5	4.7	4.4	607.9	501 (82%)
	DEFRA	16	13.5	406.6	315	1.8	1.5	57.4	51.1	6.6	5.7	488.4	386.8 (79%)
	Gössling *et al.* (2005)	11.8		496		1.4		65.8		4.3		579.3	
33	Ecoinvent	3.4	3	519.6	418.4	2	1.7	121.8	119	29.8	28.9	676.6	571 (84%)
	DEFRA	3.2	2.7	406.6	315	1.8	1.5	114.8	102.2	31.4	30.2	557.8	451.6 (81%)
	Gössling *et al.* (2005)	2.5		496		1.4		131.6		28.4		659.9	
34	Ecoinvent	5.1	4.5	519.6	418.4	2	1.7	60.9	59.5	3.6	3.2	591.2	487.3 (82%)
	DEFRA	4.8	4	406.6	315	1.8	1.5	57.4	51.1	3.6	3.3	474.2	374.9 (79%)
	Gössling *et al.* (2005)	3.8		496		1.4		65.8		2.9		569.9	
35*	Ecoinvent	53.1	43.7	650.8	524	2	1.7	60.9+11.65	59.5+11.65	0.6	0.5	779	641 (82%)
	DEFRA	41.2	34.8	509.2	394.5	1.8	1.5	57.4+11.65	51.1+11.65	0.5	0.4	621.8	494 (79%)
	Gössling *et al.* (2005)	30.3		621.2		1.4		65.8+11.65		0.4		730.8	
36	Ecoinvent	5.9	4.9	508	409	2	1.7	60.9	59.5	16.8	14.7	593.6	489.8 (83%)
	DEFRA	4.6	3.9	397.5	308	1.8	1.5	57.4	51.1	14.3	12.9	475.6	377.4 (79%)

* These estimates include the GHG emissions from hotel stay in the UK as this respondent arrived to the airport on the day before flight departure and stayed overnight at the airport hotel. The value of the GHG emissions from a 1 night hotel stay (i.e. 11.65 kg) in the UK is from Table 4.3 (see Filimonau *et al.* 2011b in Appendix 2 for details).

	Gössling *et al.* (2005)	**3.4**		**485**		**1.4**		**65.8**		**11.9**		**567.5**	
37	Ecoinvent	**18.8**	*15.5*	**508**	*409*	**2**	*1.7*	**60.9**	*59.5*	**3.4**	*3.2*	**593.1**	*488.9 (82%)*
	DEFRA	**14.6**	*12.3*	**397.5**	*308*	**1.8**	*1.5*	**57.4**	*51.1*	**3.6**	*3.4*	**474.9**	*376.3 (79%)*
	Gössling *et al.* (2005)	**10.7**		**485**		**1.4**		**65.8**		**3**		**565.9**	
38	Ecoinvent	**3.1**	*2.6*	**587.4**	*472.9*	**2**	*1.7*	**60.9**	*59.5*	**0.6**	*0.6*	**654**	*537.3 (82%)*
	DEFRA	**2.4**	*2*	**459.6**	*356.1*	**1.8**	*1.5*	**57.4**	*51.1*	**1**	*0.8*	**522.2**	*411.5 (79%)*
	Gössling *et al.* (2005)	**1.8**		**560.7**		**1.4**		**65.8**		**0.5**		**630.2**	
39	Ecoinvent	**44.7**	*36.8*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**5.7**	*5.2*	**632.9**	*521.6 (82%)*
	DEFRA	**34.7**	*29.3*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**5.3**	*5.1*	**505.8**	*402 (79%)*
	Gössling *et al.* (2005)	**25.5**		**496**		**1.4**		**65.8**		**4.8**		**593.5**	
40	Ecoinvent	**5.8**	*5.1*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**-**		**588.3**	*484.7 (82%)*
	DEFRA	**5.4**	*4.6*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**-**		**471.2**	*372.2 (79%)*
	Gössling *et al.* (2005)	**4.3**		**496**		**1.4**		**65.8**		**-**		**567.5**	
41	Ecoinvent	**28.5**	*23.4*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**0.3**	*0.3*	**611.3**	*503.3 (82%)*
	DEFRA	**22.1**	*18.6*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**0.5**	*0.4*	**488.4**	*386.6 (79%)*
	Gössling *et al.* (2005)	**16.2**		**496**		**1.4**		**65.8**		**0.3**		**579.7**	
42	Ecoinvent	**15.3**	*12.6*	**575.5**	*463.4*	**2**	*1.7*	**121.8**	*119*	**11**	*9.9*	**725.6**	*606.6 (84%)*
	DEFRA	**11.9**	*10*	**450.3**	*348.9*	**1.8**	*1.5*	**114.8**	*102.2*	**10.2**	*9.2*	**589**	*471.9 (80%)*
	Gössling *et al.* (2005)	**8.7**		**549.3**		**1.4**		**131.6**		**8.7**		**699.7**	
43	Ecoinvent	**1.6**	*0.4*	**519.6**	*418.4*	**2**	*1.7*	**60.9**	*59.5*	**34.7**	*29*	**618.8**	*509 (82%)*
	DEFRA	**6.7**	*5.8*	**406.6**	*315*	**1.8**	*1.5*	**57.4**	*51.1*	**27.5**	*23.6*	**500**	*397 (79%)*
	Gössling *et al.* (2005)	**3.1**		**496**		**1.4**		**65.8**		**20.9**		**587.2**	
TOTAL	Ecoinvent	**698.8**	*573.4*	**23275.7**	*18741.5*	**84.2**	*72.5*	**3862.8**	*3774*	**648.5**	*596.3*	**28570**	*23757.7 (83%)*
	DEFRA	**560.9**	*476.1*	**18212.5**	*14110.5*	**78.8**	*66.2*	**3640.8**	*3241.2*	**657.1**	*602.3*	**23150.1**	*18496.3 (80%)*
	Gössling *et al.* (2005)	**410.5**		**22217.7**		**62**		**4173.6**		**538.2**		**27402**	
Sample average	Ecoinvent	**16.3**	*13.3*	**541.3**	*435.8*	**2**	*1.7*	**89.8**	*87.8*	**15.1**	*13.9*	**664.5**	*552.5 (83%)*
	DEFRA	**13**	*11.1*	**423.6**	*328.2*	**1.8**	*1.5*	**84.7**	*75.4*	**15.3**	*14*	**538.4**	*430.2 (80%)*
	Gössling *et al.* (2005)	**9.5**		**516.7**		**1.4**		**97.1**		**12.5**		**637.2**	

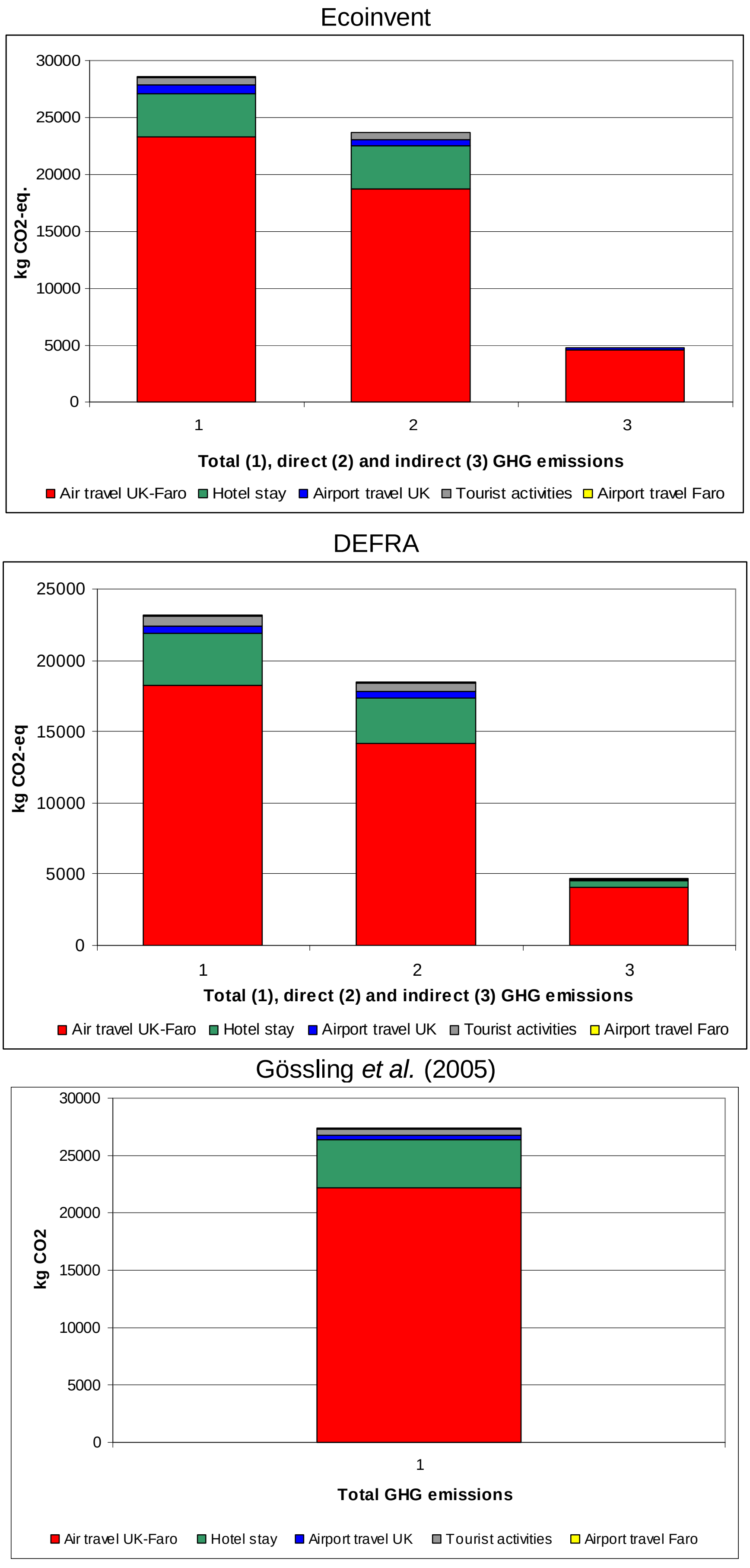


Figure 7.12. Total, direct and 'indirect' GHG emissions for the survey sample from the holiday package in the Algarve, as estimated by different methods.

When the relative carbon contribution of the holiday package elements to the total GHG emissions from the holiday package is assessed, all methods agree that the transit ('air travel') element is responsible for the largest share, i.e. around 80%, with hotel stay being the second primary contributor, i.e. 14-16% (Figure 7.12). The contribution of other holiday travel elements to the overall picture is negligible.

When the individual carbon footprints from interviewees are assessed in detail (Figure 7.13), some respondents demonstrate the carbon profiles which are slightly different from the sample average. According to Ecoinvent, for example, 14 (or 33% of the survey sample) interviewees (respondent codes 5, 7, 10, 15, 17-21, 27-29, 33 and 42) have 20-29% of the total GHG emissions produced by the non-transit elements. These stem predominantly from the hotel stay, motorised water activities and car rentals. Likewise, DEFRA suggests that 10 (23%) respondents (respondent codes 2, 10, 15, 17-21, 27 and 33) have 25-31% of the total carbon footprint arisen from the non-transit elements of the holiday package, where hotel stay is a primary contributor. Finally, Gössling *et al.* (2005) estimate that 16 (37%) interviewees (respondent codes 2, 4, 5, 10, 15, 17-21, 25-27, 29, 33 and 42) have significant quantities of GHG emissions (20-27%) stemming from the non-transit elements. The larger share of the non-transit elements in the total GHG emissions from the holiday package in the Algarve is typical for interviewees with longer durations of stay.

This finding reinforces the traditional argument that the transit element of holiday travel produces the overwhelming majority of GHG emissions. This review has however shown that the non-transit elements may also make a noticeable contribution to the total carbon footprint from holiday travel. This contribution can be further enhanced, should a tourist destination closer to the UK be considered for analysis. A scenario analysis conducted in 8.3 aims to provide an in-depth insight into this issue.

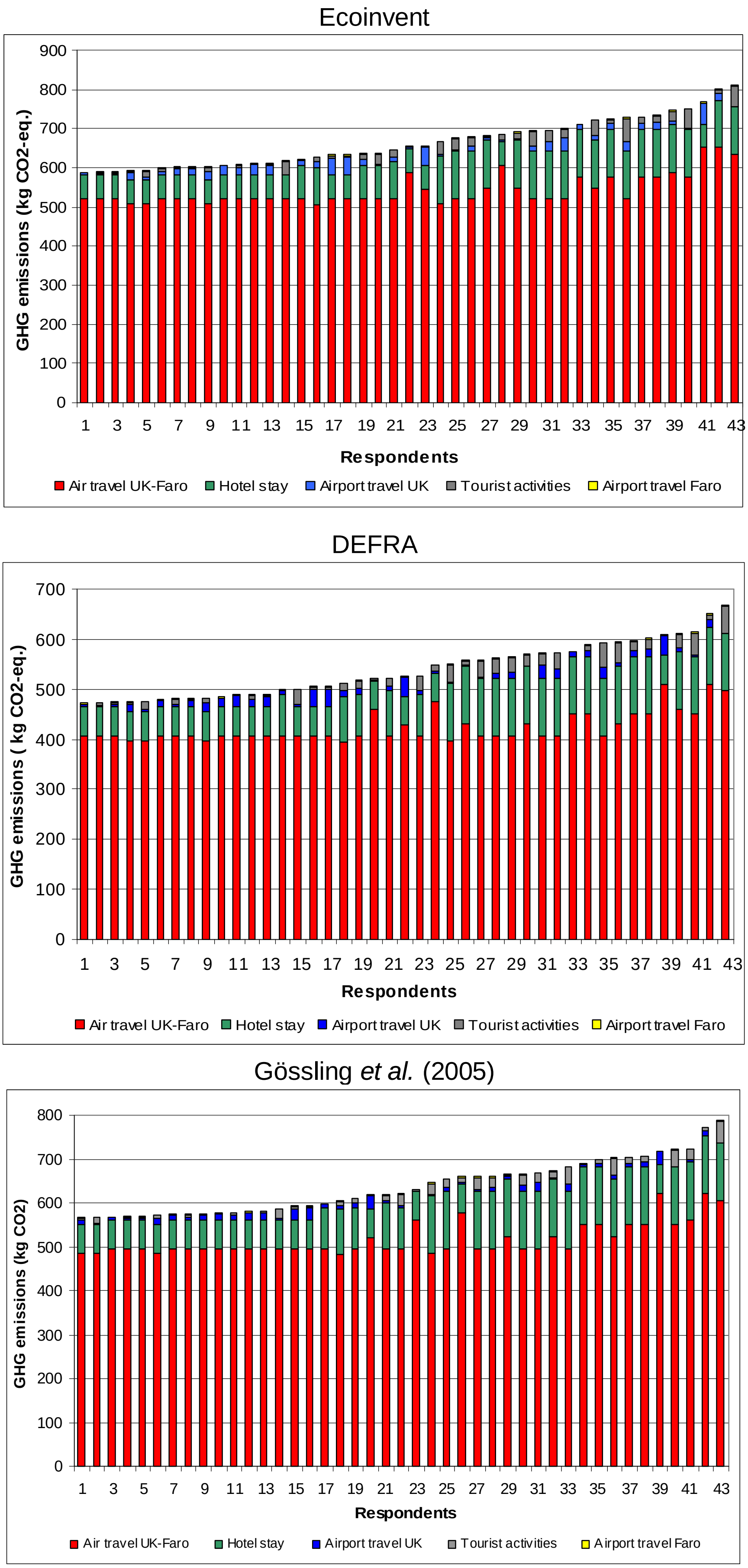


Figure 7.13. Total GHG emissions for individual tourists from the holiday package under review; ‘per holiday travel element’ distribution, estimates by different methods.

Further analysis shows that the 'indirect' GHG emissions have a profound share in the total carbon footprint from the holiday package in the Algarve, i.e. circa 10-20% (Figure 7.14), and should therefore not be ignored in carbon impact appraisal of tourism. The largest 'indirect' carbon requirements are typical for air travel which is responsible for 90-95% of the total amount of the 'indirect' GHG emissions (Figure 7.12). This finding suggests that the relative carbon significance of the transit element of holiday travel will be reduced, should the carbon footprint analysis be based on the direct GHG emissions only. In the case of the holiday package in the Algarve, for instance, the share of air travel in the total carbon footprint from the survey sample decreases, on average, to about 75%, when *only the direct* GHG emissions are taken into account.

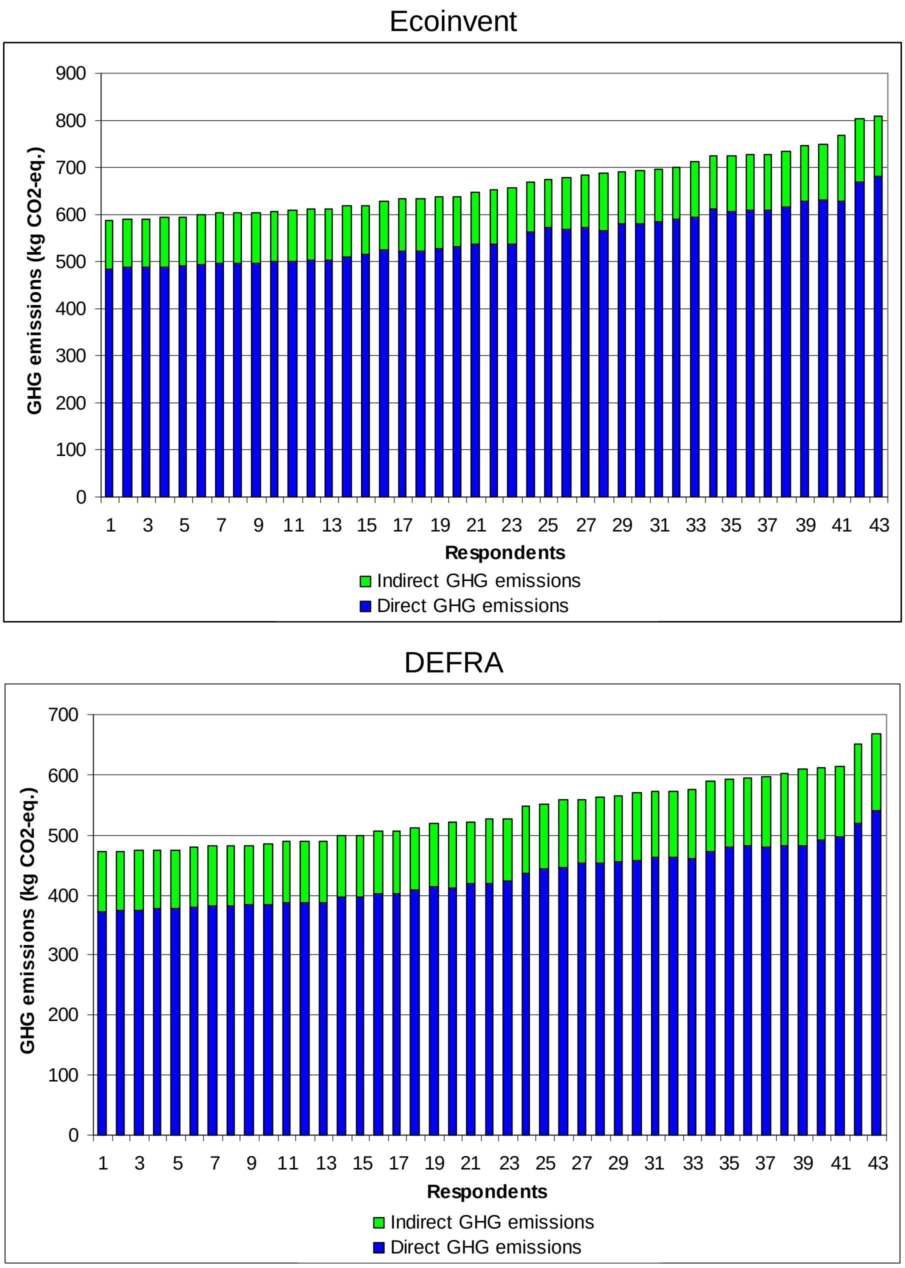


Figure 7.14. Direct versus 'indirect' GHG emissions for the survey sample from the holiday package in the Algarve.

7.3.1 Making holistic estimates of the GHG emissions from holiday travel: a hybrid DEFRA-Ecoinvent approach

A critical review of the methods for carbon impact appraisal of holiday travel has demonstrated that each approach has its weaknesses and strengths. As the primary objective of this study is to identify a technique which would be capable to produce the *most accurate and comprehensive* estimates of the GHG emissions from different elements of a holiday package, it is argued that a joint (hybrid) approach needs to be developed.

A new, hybrid approach should be based on the Ecoinvent and DEFRA methodologies using the GHG emission factors from DEFRA as a basis for estimates. This is because they are free to access, accurate and up-to-date. Another important feature is that, in terms of energy use, they are capable of estimating the carbon footprint from the energy *consumed not produced*, i.e. the additional GHG emissions related to the transmission and distribution losses are taken into account. In addition, the GHG emission factors from DEFRA do not suffer from some methodological inconsistencies attributable to the Ecoinvent method like, for example, in the case of the definition of short-haul flights for air transportation.

By employing the GHG emission factors from DEFRA, a new hybrid approach will be capable of covering the following two dimensions of the carbon footprint from holiday travel:

1) the direct carbon footprint from energy use and/or fuel combustion (energy transmission and distribution losses inclusive) and

2) the 'indirect' GHG emissions associated with fuel production, transmission, distribution and delivery to a final user, i.e. the fuel chain-related 'indirect' GHG emissions.

By adding the Ecoinvent element, this joint methodology will be refined as

3) the 'indirect' carbon footprint from the energy-generating and transport-related infrastructure and capital goods will be taken into account.

A new hybrid approach will then be capable of estimating the *maximum* possible extent of the 'indirect' GHG emissions from holiday travel. This is important as most existing estimates of the carbon footprint from tourism do not address the 'indirect' carbon impacts at all and others can address only some of their specific dimensions. Importantly, such a hybrid approach for carbon footprint assessment has already been discussed in the literature but only as a holistic method for estimating the GHG emissions from households (see, Norwegian household carbon calculator 2010). A joint DEFRA-Ecoinvent approach has never been employed in tourism.

Table 7.15 lists the hybrid GHG emission coefficients for different elements of a holiday package which have been developed by merging the Ecoinvent and DEFRA methods. The analysis shows that the capital infrastructure-related 'indirect' GHG emissions from Ecoinvent can significantly enhance the DEFRA's 'direct + fuel chain-related 'indirect'' estimates of carbon footprints from transport. The largest contribution of the capital goods and infrastructure can be observed for air (21%), car (18-19%), train (16%), and coach travel (15%). The share of the 'indirect' capital goods and infrastructure-related carbon footprint is lower for energy consumption in hotels, 10% for LPG use and 1% for electricity use, and 6% for bus travel. All these values are in fairly good agreement with Frischknecht *et al.* (2007a) who found that the capital goods and infrastructure may contribute, on average, 16% to the total GHG emissions from transport and 1-2% to the carbon footprints from electricity consumption.

Table 7.15. The GHG emission factors for different elements of a holiday package; a new, hybrid DEFRA-Ecoinvent carbon footprint assessment method (kg CO_2-eq.).

What is assessed?	**Unit of measurements**	**Direct + fuel chain-related 'indirect' GHG emissions, as estimated by DEFRA**	**Capital goods and infrastructure-related 'indirect' GHG emissions, as estimated by Ecoinvent**	**Total GHG emissions, hybrid DEFRA-Ecoinvent**
Transport				
Bus	pkm	0.16	0.0095	0.17
Coach		0.0276	0.0036	0.0312
Passenger car		0.083	0.019	0.102
Passenger car (diesel) = Taxi		0.08	0.017	0.097
Train		0.065	0.012	0.077
Air travel		0.12	0.03	0.15
Hotel stay				
Electricity	guest night	7.3	0.1	7.4
LPG		0.9	0.1	1.0

Table 7.16 presents the estimates of the GHG emissions from the survey sample made with the help of a hybrid DEFRA-Ecoinvent approach. It is argued that these figures represent the most accurate and rigorous estimates of the carbon footprint from the holiday package in the Algarve. If compared to other methods, the values of the total carbon footprint from a joint approach are slightly lower than the estimates of the total GHG emissions from Ecoinvent, slightly larger than the numbers from Gössling *et al.* (2005) and circa 20% larger than the figures from DEFRA. Here, air travel again demonstrates the dominant contribution.

A hybrid DEFRA-Ecoinvent method shows that *all dimensions* of the 'indirect' GHG emissions account for a significant portion of the total carbon footprint from survey respondents, i.e. 25-30% (Figure 7.15). The largest share of the 'indirect' carbon impacts is attributable to air travel. If compared to the figures of the 'indirect' carbon footprint from tourism and leisure-related activities reported elsewhere (Table 2.3), the values from this case study are slightly higher. This is arguably because they are more up-to-date, cover a fuller range of 'indirect' carbon footprints and represent an assessment of an aggregate tourism product. The assessments previously reported in the literature are based on generic estimates, rather than accurate evaluations, and/or represent large-scale carbon impact appraisal studies.

A significant share of the 'indirect' GHG emissions in the total carbon footprint from a holiday package is an important finding as it implies that existing carbon impact appraisal studies, based on the methods which are unable to estimate the 'indirect' carbon requirements from tourism, are likely to underestimate the actual carbon intensity of tourism products. A 'full' picture of the modeled reality can be obtained only when the 'indirect' GHG emissions are addressed and holistically assessed.

Another interesting finding relates to the sample-average carbon footprint from tourist activities: while 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, the results of this analysis suggest that this figure is likely to be an overestimation. The sample-average GHG emissions from tourist activities estimated in this study equate 17 kg of CO_2-eq., while the carbon footprints equal and/or exceeding 40 kg have been produced by only 5 (12%) respondents. This implies that tourist activities call for more attention in future tourism carbon footprint assessment research as there is a clear need to have more accurate and holistic estimates of their carbon intensities.

Table 7.16. GHG emissions from the survey sample; a hybrid DEFRA-Ecoinvent approach.

Respondent	Airport travel UK	Air travel	Airport travel Faro	Hotel stay	Tourist activities	TOTAL
1	15.4	507.8	2.9	84.0	15.7	625.7
2	18.9	562.4	2.9	117.6	19.7	721.4
3	25.4	507.8	2.9	58.8	2.6	597.4
4	9.0	507.8	2.9	84.0	29.8	633.4
5	3.5	562.4	2.9	117.6	47.8	734.1
6	11.2	507.8	2.9	92.4	17.1	631.3
7	1.5	536.8	2.9	117.6	24.1	682.9
8	11.2	507.8	2.9	84.0	-	605.8
9	47.1	534	2.9	58.8	-	642.7
10	3.3	496.5	2.9	117.6	46.6	666.9
11	8.6	507.8	2.9	58.8	9.8	587.9
12	16.6	507.8	2.9	58.8	1.8	587.8
13	43.4	507.8	2.9	58.8	5.6	618.5
14	16.8	507.8	2.9	58.8	2.9	589.1
15	12.3	507.8	2.9	117.6	31.3	671.9
16	7.1	507.8	2.9	58.8	3.0	579.6
17	26.1	507.8	2.9	117.6	57.3	711.6
18	24.2	507.8	2.9	117.6	39.1	691.5
19	13.6	507.8	2.9	117.6	36.0	677.9
20	34.0	507.8	2.9	117.6	21.9	684.1
21	1.2	619.9	2.9	117.6	54.4	795.9
22	4.8	536.8	2.9	117.6	7.6	669.7
23	22.0	496.5	2.9	58.8	8.8	589.0
24	23.6	507.8	2.9	58.8	-	593.1
25	15.1	493.5	2.9	92.4	14.0	617.8
26	11.2	562.4	2.9	117.6	-	694.1
27	9.6	536.8	2.9	117.6	40.4	707.3
28	9.9	574	2.9	117.6	27.7	732.1
29	14.6	562.4	2.9	117.6	19.3	716.8
30	17.3	636	2.9	117.6	11.2	785.0
31	4.9	591.6	2.9	58.8	13.6	671.7
32	19.7	507.8	2.9	58.8	6.9	596.0
33	4.9	507.8	2.9	117.6	32.2	665.4
34	7.4	507.8	2.9	58.8	4.0	580.9
35	50.7	636	2.9	58.8	0.6	748.9
36	5.7	496.5	2.9	58.8	16.3	580.1
37	18.0	496.5	2.9	58.8	3.8	579.9
38	3.0	574	2.9	58.8	1.0	639.7
39	42.6	507.8	2.9	58.8	5.8	617.9
40	8.5	507.8	2.9	58.8	-	577.9
41	27.2	507.8	2.9	58.8	0.5	597.1
42	14.6	562.4	2.9	117.6	13.5	710.9
43	7.9	507.8	2.9	58.8	33.2	610.6
TOTAL	**693.8**	**22746.7**	**122.8**	**3729.6**	**726.9**	**28019.7**
%, TOTAL	**2.5**	**81.2**	**0.4**	**13.3**	**2.6**	**100.0**
Sample average	16.1	529	2.9	86.7	16.9	651.6

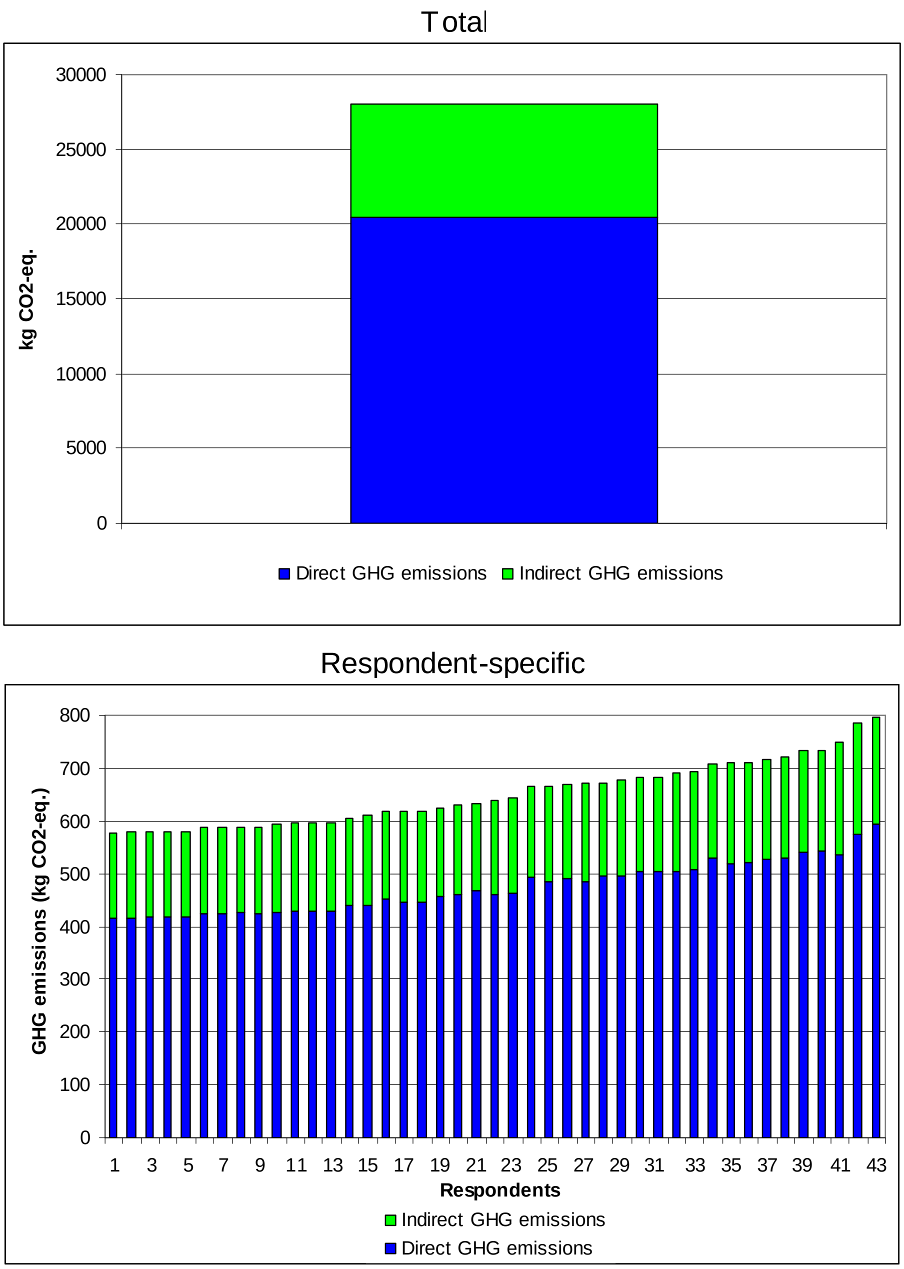


Figure 7.15. Direct versus 'indirect' GHG emissions for the survey sample from the holiday package in the Algarve, a hybrid DEFRA-Ecoinvent method.

Last but not least, this study aimed to better understand the variance in the 'daily' carbon intensity of holiday travel for tourists with different durations of stay at the destination. When the 'daily' GHG emissions from tourist activities only (excluding accommodation and transportation to/from the destination) are estimated, the analysis demonstrates that holidaymakers with a longer duration of stay produce the double carbon footprint compared to short-staying tourists, i.e. 1.9 versus 0.8 kg of CO_2-eq. per night, respectively. This may suggest that holidaymakers staying at the destination longer tend to take part in more energy and carbon-intense tourist activities.

If the accommodation element is added to tourist activities, the analysis shows no significant difference in the 'daily' carbon intensities for holidaymakers staying at the destination for 7 and 14 nights. The 'daily' carbon footprint equates to about 8 and 10 kg of CO_2-eq. per night, respectively.

When the *total* individual GHG emissions (including transportation to/from the destination, accommodation and tourist activities) from the holiday package in the Algarve are linked to the duration of stay, the analysis indicates that tourists staying at the destination for 7 nights produce over 80 kg of CO_2-eq. per night while holidaymakers with 14 nights of stay generate only about 50 kg of CO_2-eq. per night. This suggests that the primary contribution to the 'daily' carbon intensity of holidays is made by transportation to/from the destination.

The discrepancy further increases, should the estimates of GHG emissions be made on the 'net' basis (see 6.2.5). Compared to holidaymakers staying in the Algarve for 7 nights, tourists with 14 nights of stay may in addition save up to 38.5 kg (i.e. 5.5 kg per night) of CO_2-eq. by not consuming energy in the UK. All this implies that, in carbon footprint terms, going on holiday to the Algarve seldom, but staying at the destination longer, is much more beneficial than undertaking frequent but short holidays. This finding is in agreement with the literature (Gössling *et al.* 2005; Peeters *et al.* 2006; Peeters and Schouten 2006).

7.4. LIMITATIONS

This study has limitations. First, the data on energy consumption at HV Algarve and tourist statistics represent 2009, the year with the most recent aggregate data available from TUI Travel and HV Algarve, while interviews were conducted among the 2010 tourist cohort. According to TUI Travel, there are no significant inter-annual variations in the number and socio-demographic profile of tourists sent to HV Algarve (Thomas Lynch, Lifestyle Product Development Manager – Families, TUI Travel PLC, personal communication, 17 March 2010). Most of the TUI Travel clients are families with children; hence it is argued that a survey on tourist activities undertaken in 2010 is fairly well representative of 2009 and that its results can be extrapolated to describe the 2009 situation.

Another limitation related to the 'data age' arises from the schedule of charter flights to/from airport in the UK in 2009 and 2010. Many of the charter flights to the Algarve organised by TUI Travel in 2010 departed early mornings and this might have affected the means of transport selected by interviewees to get to/from airport (see 6.2.2.3). However, according to TUI Travel, the flight departure/arrival times have not changed much in the past few years due to the organisational issues and high costs related to procuring more convenient time slots, especially in busy London airports. Therefore, it is argued that the 2010 tourist responses with regard to airport transportation can be generalised and applied to the analysis of tourists in 2009.

Second, the number and range of tourist activities undertaken by tourists at the destination may have seasonal variations as these can be affected by a number of factors, such as weather, age, financial situation, family status of tourists and availability of specific tourist activities. As the effect of these factors is impossible to predict, it is argued that a snap-shot of tourist activities undertaken by the survey sample in 2010 is adequate to understand the range of tourist activities undertaken by other tourists in different seasons.

The third important limitation of this study is exclusion of waste generation from the carbon footprint analysis. Waste generation is sometimes considered as an indispensable element of holiday travel (see, for example, Patterson *et al.* 2007; Peng and Guihua 2007). Furthermore, there is evidence that waste generation in tourist accommodation facilities may have a significant impact on the environment (see, for example, Chan and Lam 2001; Radwan *et al.* 2010; Trung and Kumar 2005), also in carbon footprint terms, especially in large holiday resorts and in popular tourist destinations. The issue of *food* wastage is of particular interest. The case study under review is based on an 'all-inclusive' holiday package; it is deemed that a high proportion of the 'all-inclusive' food can be wasted due to the reckless behaviour of hotel guests. In fact, more research on food wastage by tourists in general, and more comparative research on food wastage in bed-and-breakfast/half board hotels versus 'all-inclusive' hotels in particular, is recommended. This notwithstanding, waste generation was not considered in this case study due to the absence of the necessary data on the volumes of refuse produced by the HV Algarve guests in 2009. Data quality issues on waste generation are not uncommon in the hotel sector (Radwan *et al.* 2010); hence, the exclusion of this aspect of holiday travel can be reasonably explained.

Fourth, the holiday package in the Algarve is based on a hotel which is a modern built constructed according to the latest insulation and energy-saving standards. In recognition of its efforts applied for reducing impacts on the environment, HV Algarve has received a golden sustainability award from Travelife Foundation. This imposes another limitation as many holiday packages are not necessarily based on such modern and environment-friendly hotels. This implies that the findings of this study may not be representative of some of the holiday packages existing in the UK tourism market. The carbon footprint from the hotel stay estimated in this study may therefore correspond to the *lower limit* of the possible range of the GHG emissions from hotels of a similar class.

Fifth, the energy consumption in HV Algarve was assessed as an aggregate for two major hotel buildings, i.e. Alto da Colina 1 and 2. Given that Alto da Colina 2 building is three times smaller than Alto da Colina 1 and since it hosts only guest rooms, it is argued that disaggregation of the hotel's energy bill would be useful to better understand how the presence of reception, laundry, communal and catering areas affects the total energy use and consequent GHG emissions in Alto da Colina 1 and the hotel complex as a whole. Such disaggregation was reported by the resort management as not feasible due to financial and technical constraints. This is in line with the literature which found that disaggregation and detailed monitoring of energy flows in buildings is regarded by many hotels as prohibitively complex and expensive (Bohdanowicz *et al.* 2001a). As a consequence, the absence of disaggregated data and poor quality energy consumption information provided by hotels is a common problem in the tourism accommodation sector (see Filimonau *et al.* 2011b in Appendix 2 for details). Hence, this study is based on the aggregate data only. It is argued that the availability of accurate, detailed data on energy consumption may enable monetary savings for hotels and facilitate an in-depth analysis of energy use and consequent GHG emissions from hotel operations for researchers.

Sixth, this study did not account for the additional 'indirect' GHG emissions associated with the full life cycle of food, i.e. the food chain-related carbon footprint. The food chain generates carbon footprint at all stages of its life cycle, i.e. from farming process and its inputs, through to manufacture, storage, transportation, retailing, food preparation and waste disposal (Garnett 2011). Only the carbon impacts arising from food preparation/cooking were estimated in this review. Concurrently, Garnett (2011) and Uitdenbogerd *et al.* (1998 cited Jungbluth *et al.* 2000) argue that these can be responsible for only 10-25% of the total life cycle GHG emissions from foodstuffs. While it is acknowledged that the *full* carbon footprint from food can be significant and should therefore be assessed, whenever possible (Gössling *et al.* 2011), this issue has been excluded from analysis for the purpose of data unavailability.

7.5. SUMMARY

This chapter has conducted a detailed carbon impact appraisal of the holiday package in the Algarve. The relative contribution of different elements of the holiday package to the total GHG emissions has been revealed. The share of the 'indirect' carbon requirements in the total carbon impact from the holiday package has been evaluated. The difference in estimates of the GHG emissions produced by the key methods for carbon impact assessment in tourism has been identified and the reasons for discrepancy reviewed. A new, hybrid method for holistic carbon impact appraisal of tourism products which is capable of estimating the direct and all (currently known) dimensions of the 'indirect' GHG emissions has been proposed.

The analysis has shown that the carbon intensity of individual tourist profiles varies depending on a number of different factors. The next chapter applies a sensitivity analysis to better understand what factors make the foremost contribution to the variance in individual GHG emissions from the holiday package in the Algarve.

The analysis has also indirectly indicated that although air travel has a dominant share in the total carbon footprint from the holiday package in the Algarve, the contribution of the non-transit elements can also be significant, especially if the destination is located closer to the UK and if there are alternative means of transportation to/from the destination and if tourists are staying at the destination longer. The next chapter conducts a comparative analysis of different travel scenarios to demonstrate how the choice of travel to/from destination along with the duration of stay affects the magnitude of the GHG emissions from holiday travel.

CHAPTER 8. ASSESSING THE GHG EMISSIONS FROM THE HOLIDAY PACKAGE: SENSITIVITY AND SCENARIO ANALYSES

8.1 INTRODUCTION

This chapter conducts a sensitivity analysis on a new, hybrid DEFRA-Ecoinvent method for carbon impact appraisal in tourism, to demonstrate the variations in carbon intensity of the holiday package and its specific elements when alterations in the primary parameters (variables) of the reviewed holiday package tour are made. A scenario analysis is further applied to better understand how the choice of transportation to/from the short-haul destination affects the total carbon footprint from holiday travel. The results of analyses are critically evaluated with reference to the development of prospective carbon footprint mitigation measures for holiday packages with specific parameters.

8.2 SENSITIVITY ANALYSIS

Although a sensitivity analysis is a recommended, but yet optional, element of many LCA-based studies, the awareness about the value it adds to assessment is growing. Sensitivity analysis is particularly useful as it helps evaluate the uncertainty, i.e. how the outcome of environmental appraisals is affected by the variations in assumptions, methods and data quality (Junnila and Horvath 2003a).

Scenario analysis is often referred to as one type of a sensitivity analysis in LCA (LCEA) (Junnila and Horvath 2003a). In this context, it is defined as a test of different choices of the used product or service system, input parameters and external factors (Junnila and Horvath 2003a; Pesonen *et al.* 2000).

Pesonen *et al.* (2000) suggest two types of scenario analysis: What-if and Cornerstone. The What-if scenarios are used when different alternatives to existing product or service system (and its specific elements) are to be compared and/or when some specific changes within the present product or service system need to be analysed and their implications for environmental impacts reviewed. This type of scenario analysis usually has a short time horizon and provides quantitative comparisons of the selected alternatives (Pesonen *et al.* 2000). In contrast, the Cornerstone scenarios are based on a long-term analysis; they provide qualitative comparisons, are primarily applied for strategic planning and can serve a basis for more detailed What-if scenario analyses. The What-if scenario analysis is more suitable for this study as the alternative variables (input parameters) of the holiday package will be tested against the established ones; hence, it will be employed in this review.

Since the most comprehensive and accurate estimates of the GHG emissions from holiday travel can be obtained by applying a hybrid DEFRA-Ecoinvent approach (see 7.3.1), it will be used for a sensitivity analysis. Table 8.1 lists the variables under test and describes their tested parameters.

Apart from variables considered in Table 8.1, the effect of different means of transportation to/from the Algarve can also be tested. Flying is the only mode of travel considered in this study. Although its carbon intensity could be tested against the carbon intensity attributable to other means of transportation, such an analysis has not been conducted. It is argued that it has a limited practical value as the Algarve (Faro) can hardly be reached from the UK by surface transport. This is because of significant time requirements and potential high costs of the prolonged overland travel. Scenario analysis conducted in section 8.3 will carry out an in-depth evaluation of the effect that the choice of transportation to/from the short-haul destination makes on the total GHG emissions from holiday travel.

Table 8.2 presents the results of a sensitivity analysis. It indicates that the distance flown to/from the Algarve is a parameter making the foremost impact on the magnitude of the GHG emissions from the holiday package under review. The significance of air travel can be illustrated by the following comparison: the carbon footprint from all non-transit elements of the holiday package under the 'basic profile' scenario settings equates to circa 120 kg. The same amount of additional GHG emissions is produced as a result of flying from London to Glasgow.

Duration of stay and the number of tourist activities undertaken by survey respondents at the destination also affect the total carbon footprint from the holiday package, although the relative significance of their contribution is almost half of that from air travel.

The distance driven to the airport in the UK may also have a noticeable effect, should it be covered by such carbon-intense modes of transport as car and taxi. In this respect, it is argued that TUI Travel could undertake more pro-active measures for reduction of the GHG emissions from airport transport. This could be achieved by, for example, offering more 'sociable' time slots for flight departures/arrivals in the UK. It is deemed that this might reduce the number of airport journeys undertaken by car (taxi) and encourage more active use of public transport. This measure would have more effect if combined with additional incentives which could be offered to tourists traveling to/from airport in the UK by public transport. This might take the form of discounts for future holiday bookings or packages including coach or train transport.

Table 8.1. Parameters under test for a sensitivity analysis, the holiday package in the Algarve.

Holiday package element (variable)	Basic parameter	Why has it been chosen?	Parameters to test
Travel to/from UK airport	**Car** as a primary means of transportation	The most popular means of transportation reported by interviewees	Alternative means of transportation: ***coach, taxi and train***
	168.9 km as an average distance driven by the survey sample respondents	Significant variance in distances covered by survey respondents to get to/from airport + no information on the distance travelled by an average TUI Travel client holidaying in HV Algarve	Minimum (***12 km***) and maximum (***496.6 km***) distances covered by the survey sample respondents, see Table 6.7
	Tourists travel to/from airport **independently**, no airport drop-off by other family members / acquaintances	'Car (with my family)' as the most popular mode of travel to/from the airport reported by interviewees	Tourists are brought to / from the airport by other family members / acquaintances implying ***double travel distances***
Travel UK-Faro	**Gatwick** as a departure/arrival airport, return travel distance = **3374 km**	The most popular airport with the TUI Travel clientele holidaying in HV Algarve	Other departure/arrival airports in the UK, namely Glasgow with max return flying distance of ***4226 km*** and Cardiff with min return flying distance of ***3279 km***
Airport travel Faro	**Coach** as a means of transportation	Default transport mode for airport transfers offered by TUI Travel to its clientele	Alternative means of transportation, not organised by TUI Travel ***taxi*** and ***bus***
Hotel stay	**10 nights**	The average duration of stay for the TUI Travel clientele holidaying in HV Algarve.	Other durations of stay available for the TUI Travel clientele, namely ***7*** (min) and ***14 nights*** (max)
	Energy and GHG emissions embodied in a hotel building are excluded	No data on the non-operational energy use and consequent carbon footprint within the HV Algarve building life cycle	The evidence from the literature stating that the non-operational carbon impacts from buildings may account for about 15% of the total GHG emissions
Tourist activities	Tourist activities representing an **'average respondent' profile**, see Table 6.9	Significant variance in tourist activities undertaken by survey respondents in the Algarve	***Min*** and ***max*** ranges of tourist activities undertaken by the survey sample respondents in the Algarve
Other – hotel stay in the UK	**No hotel stay** in the UK	Despite early departures and late arrivals of the TUI Travel chartered flights, the majority of respondents arrived/left the airport on the day of departure/arrival	***1 night stay*** at the airport hotel in the UK for tourists unable to arrive/leave the airport on the day of departure/arrival
Other – 'net' carbon footprint	**Gross GHG emissions** from the basic profile	Gross carbon footprint is currently the primary method for estimating the GHG emissions from holiday travel	***'Net' carbon footprint***, i.e. the difference between the gross GHG emissions produced when on holidays and the GHG emissions saved as a result of being away from home

Table 8.2. Results of a sensitivity analysis for different elements of the holiday package in the Algarve.

Holiday package component (holiday travel variable)	Basic profile	Parameter under test	GHG emissions, kg CO_2-eq.	Deviation from the basic parameter, kg CO_2-eq.	Deviation from the basic parameter, %
Basic profile		***-***	***623.4***	***0***	***0***
Airport travel UK, transportation mode and distance (km)	Car = 168.9 km	Coach	613.5	-4.2	-1.6
		Tax	622.6	-0.8	-0.1
		Train	619.2	-10	-0.7
		12 km	607.4	-16	-2.6
		Coach	606.7	-16.7	-2.7
		Tax	607.4	-16.1	-2.6
		Train	607.1	-16.3	-2.6
		496.6 km	656.8	+33.4	+5.4
		Coach	627.5	+4.1	+0.7
		Tax	654.4	+30.9	+5
		Train	644.4	+21	+3.4
	Double travel distance		640.7	+17.3	+2.8
Travel UK-Faro	Gatwick = 3374 km	Cardiff = 3279 km	609.2	-14.2	-2.3
		Glasgow = 4226 km	751.2	+127.8	+20.5
Airport travel Faro, transportation mode	Coach	Tax	627	+3.6	+0.6
		Bus	631.9	+8.4	+1.4
Hotel stay	10 nights	7 nights	598.2	-25.2	-4
		14 nights	657	+33.6	+5.4
		Energy embodied in hotel building is included	636	+12.6	+2
Tourist activities	'Average respondent' profile	Min range	610.2	-13.2	-2.1
		Max range	667.5	+44.1	+7.1
Other – hotel stay in the UK	No hotel stay	1 night hotel stay	635.1	+11.7	+1.9
Other – 'net' carbon footprint	Gross GHG emissions	'Net' GHG emissions	568.4	-55	-8.8

The results of a sensitivity analysis suggest that the maximum amount of GHG emissions would be produced by tourists flying to the Algarve from Glasgow, travelling long distances to/from airport in the UK by car (taxi), staying 14 nights at the destination and partaking in a large number of tourist activities. The analysis shows that, under this scenario, the total carbon footprint from the holiday package under review will increase by almost 40% compared to the basic profile. These GHG emissions can be further (about 4%) enhanced by overnight hotel stay in the UK.

In contrast, the lowest carbon footprint from the holiday package in the Algarve would be generated by holidaymakers flying from Cardiff, traveling short distances (or longer distances, but by coach) to the airport and staying 7 nights at the destination. The analysis shows that such scenario would reduce the GHG emissions from the basic profile by over 10%.

Importantly, if the carbon footprint assessment of the holiday package in the Algarve is based on the 'net' GHG emissions, the overall carbon impact from the 'basic respondent' profile reduces by almost 10%. In fact, the hotel stay in the Algarve was found to be only 30% more carbon intense than the home stay in the UK. This figure becomes even lower, should the residual energy consumption at home while on holidays be ignored. This implies that holidaymaking at HV Algarve would be not significantly more carbon-intense than staying in the UK and undertaking normal consumption activities, should the holiday package involve no travel by air.

Thus, the analysis demonstrates that air travel is responsible for the disproportionally large amounts of the GHG emissions from the holiday package in the Algarve. Figure 8.1 illustrates the approximate distances that would need to be flown by survey respondents, should equality between the carbon footprint from air travel and the GHG emissions from the non-transit elements of holiday travel be achieved (under the assumption that the holiday package settings remain unchanged). It suggests that holidaying for 14 nights in, for example, Brittany (France), under the identical to the reviewed holiday package in the Algarve travel settings, would generate the same amount of GHG emissions as the return air travel to this holiday destination.

A sensitivity analysis was also conducted to test how the original (default, not adjusted to account for a RF effect or occupancy) GHG emission factors from the carbon footprint assessment methods under review would affect the outcome of estimates, should they have been applied in this study unchanged. The respondent with the 'basic profile' was selected for a comparative assessment.

The results show (Table 8.3) that the estimates produced by the hybrid DEFRA-Ecoinvent approach are about 20% smaller than the values from the original Ecoinvent method, circa 10% larger than the figures from DEFRA and over 40% smaller than the numbers suggested by Gössling *et al.* (2005). The large discrepancy between the hybrid DEFRA-Ecoinvent approach and the method from Gössling *et al.* (2005) can be explained by the radiative forcing (RF) coefficient used by default in the latter method when assessing the carbon footprint from air travel. This coefficient increases the estimates dramatically.

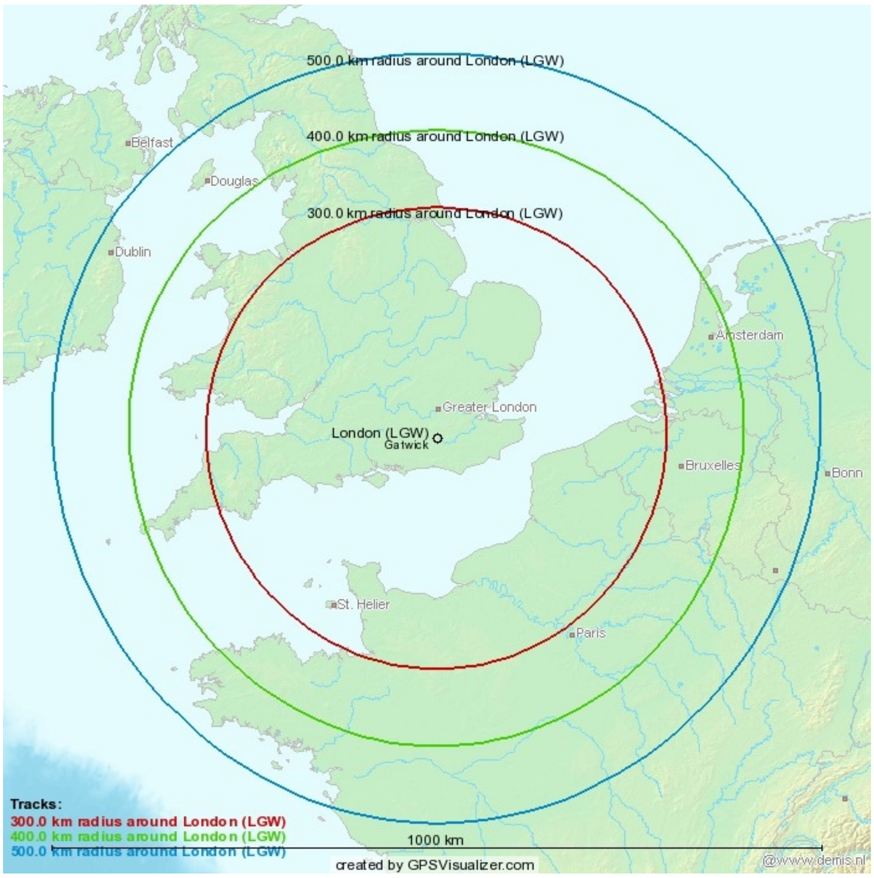


Figure 8.1. Destinations from the UK where return air travel would generate the same quantity of GHG emissions as the carbon footprint from all non-transit elements.

Source: Author. The holiday travel settings from the holiday package in HV Algarve are applied. Red circle shows destinations with the duration of stay of 7 nights, green circle – 10 nights, blue circle – 14 nights. Map created by GPS Visualizer (2010).

Table 8.3. Sensitivity analysis for a hybrid DEFRA-Ecoinvent approach, basic respondent profile, total GHG emissions.

Method	GHG emissions, kg CO_2-eq.	Deviation from the basic parameter, kg CO_2-eq.	Deviation from the basic parameter, %
Hybrid DEFRA-Ecoinvent	***623.4***	***0***	***0***
Original Ecoinvent	802.1	+178.7	+22.3
Original DEFRA	553.7	-135.9	-12.6
Original Gössling *et al.* (2005)	1451	+970.8	+43

A significant difference between the hybrid approach and Ecoinvent is predominantly due to the unfeasibly high GHG emission factors applied by default in Ecoinvent for carbon footprint assessment of short-haul intra-European flights. This, in turn, is a result of the employment of the North-American, rather than European, definition for short-haul air travel. Moreover, higher estimates of the carbon footprint produced by Ecoinvent are partially due to the lower occupancy factors suggested by this method by default for analysis of coach, car and taxi travel.

Finally, the lower values of the GHG emissions from DEFRA are mostly because of the additional 'indirect' carbon requirements imposed by the infrastructure and capital goods which are not accounted for in this method but which, concurrently, have been covered by the hybrid DEFRA-Ecoinvent approach.

To summarise, it is argued that the application of the traditional methods for carbon footprint assessment of holiday travel in this study would have yielded the estimates with a significant degree of uncertainty. It is further argued that the most accurate and comprehensive values of the GHG emissions from tourism products can be obtained by utilizing a hybrid approach developed in this study.

8.3 SCENARIO ANALYSIS

8.3.1 Rationale

The carbon footprint assessment of the holiday package in the Algarve has demonstrated that air travel makes the largest contribution to the total GHG emissions. To explore the impact of a change in mode of transport to the short-haul destination on tourism carbon footprint, a comparative analysis of the holiday packages based on different transportation alternatives is necessary. As travelling by overland means of transport to Portugal is not popular due to its relative remoteness from the UK, a comparative carbon footprint analysis of alternative travel scenarios for the Algarve, whilst possible, has little practical value. Hence, the carbon footprint appraisal of a tourist destination which lies closer to the UK and has more realistic modal alternatives, most notably direct rail links, has been undertaken. While it is acknowledged that the value of this analysis is also limited as travel preferences of tourists with regard to the selection of specific transport modes are difficult to predict, its primary goal is to compare the GHG emissions associated with different travel scenarios. It also aims to demonstrate how the relative carbon intensity of different elements of holiday travel varies, should a shorter travel distance be considered for analysis. The analysis will show how other factors such as the length of stay at the destination affects the total and holiday travel element-specific magnitudes of carbon impacts from holidays. Last but not least, the role of the 'indirect' GHG emissions in different travel scenarios will be investigated.

Another reason for conducting a multiple scenario case study is to utilise some of the data from previous work. It is argued that it is necessary to test how the relative carbon intensity of tourist activities revealed by the survey in the Algarve (see 7.3.1) compares against the GHG emissions from other elements of holiday travel under the shorter travel distance and different transport to/from the destination scenarios. Likewise, this scenario analysis aims to employ the carbon impact coefficients for tourist accommodation disclosed by the case study in Poole, UK (see 4.5.4), to better understand how these can be applied for estimates of the GHG emissions from en-route hotel stay (see 8.3.2 for details).

The destination has to fulfill the basic requirement of this review, i.e. to be short-haul. Southern France (Provence-Alpes-Cote d'Azur, Marseille prefecture) has been selected as, similar to the Algarve, it is a seaside destination. Moreover, it is popular with British tourists (Office for National Statistics 2009) and easily accessible from the UK by overland means of transportation.

8.3.2 Scope and limitations

The travel scenarios considered in this review are presented in Figure 8.2 and explained in the text. These are limited to the most feasible travel options 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. It is assumed that all overland modes of transportation cross the English Channel by Eurotunnel. It is acknowledged that ferry can be used as an alternative in the car and coach scenarios. However, the GHG emission factors from DEFRA (2010a)[19] suggest that a return journey over the channel by ferry (circa 120 km) will add only 6 kg of CO_2-eq. to the total carbon footprint of the car and coach-based holidays, while the carbon intensity coefficient from Gössling *et al.* (2005) suggests a decrease by 3 kg. As these estimates contradict, ferry trips have not been included in the analysis.

Holidaymakers are assumed to stay in a hotel in the vicinity of Marseille. Duration of stay equal to 7 nights is taken as a basic modeling scenario; additionally, 14 nights are

[19] The Ecoinvent database does not provide the GHG emission factors for ferry transport.

considered for a comparative carbon footprint analysis of different lengths of stay.

Figure 8.2. Travel scenarios for holidaymaking by Britons in Southern France.
Source: Author. Map adapted from EuropeETravel (2004).

For carbon footprint assessment of different transport modes the values of carbon intensity (along with the relevant underlying assumptions) from a hybrid DEFRA-Ecoinvent method will be used. The missing figure for long-haul rail travel will be developed herewith.

Due to the lack of data on the carbon intensity of tourist accommodation facilities and tourist activities in France, the carbon footprint analysis of these holiday travel elements will employ the GHG emission coefficients from the hotel stay in HV Algarve and tourist activities in Albufeira. The limitations of these figures have been discussed in 7.4.

Specific to tourist activities, 16.9 kg of CO_2-eq., an average value of GHG emissions calculated for a tourist sample in the Algarve (Table 7.16), will be used for analysis. It is acknowledged that this figure may be an underestimate as traveling to Marseille by overland transport may result in additional tourist activities undertaken en-route (for instance, food consumption, visits to museums and excursions in Paris). It is nevertheless argued that their carbon contribution to the total GHG emissions from holidays is small. Moreover, it will be partially accounted for through the employment of higher carbon intensity coefficients for hotel stays en-route (see Scenario 1 for details). All calculations are on per capita basis.

Scenario 1: Travel by car.

The major benefit of traveling to Southern France from the UK by car is flexibility in choosing the itinerary, overall trip duration and places visited en-route. The scenario considered in this review is based on the shortest driving distance from London to Marseille. This implies that the estimates of the carbon footprint from car travel produced in this study may represent the lower end of the possible range of the GHG emissions from driving from the UK to Southern France.

Google Maps (2011) calculate the one-way distance from London to Marseille as 1236 km; the overall trip duration is estimated as 12.5 hours. Since it is hardly possible to cover this distance by car in one go, the scenario suggests one en-route overnight stop in Paris. 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 travel.

To estimate the carbon footprint from hotel stay en-route, the study employs the GHG emission factor of 11.65 kg of CO_2-eq. per guest night calculated for hotels in Poole, UK (see 4.5.4). It is argued that this higher figure is more appropriate for analysis than the lower value of 8.4 kg of CO_2-eq. per guest night obtained for HV Algarve in Portugal (Table 7.15). The en-route hotels in Paris are deemed to be less carbon efficient than the HV Algarve resort which is a modern build certified by the Travelife eco-label. This is also due to the geographical factor (similar climatic conditions in the UK and France) and similarity in British and French national building traditions and building materials used. Moreover, the higher figure of the GHG emissions from the en-route hotel stays accounts for the additional carbon footprint arising from tourist activities undertaken en-route. The limitations of this approach are also acknowledged. Hotels in Paris are arguably busier and may therefore produce less GHG emissions per 'guest night' than the reviewed hotels in the UK. Furthermore, energy generation in France has a lower carbon footprint than energy generation in the UK due to a more significant share of nuclear fuels. However, as the scenarios considered propose only two overnight en-route hotel stays, and since the difference between the figures from the hotels in Poole, UK, and HV Algarve is not drastic (circa 3 kg), it is argued that the higher value of 11.65 kg of CO_2-eq. is acceptable for analysis.

Scenario 2: Travel by rail.

Traveling 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 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 2010; Google Maps 2011); the journey lasts approximately 7 hours and can therefore be made within a single day. For better comparability of scenarios, two overnight stays in Paris are nevertheless included into analysis.

As the main review does not provide a GHG emission factor for long-distance international trains, it has been developed as follows:

The hybrid DEFRA-Ecoinvent carbon intensity value is made of the total (direct and 'indirect') GHG emission factor from DEFRA plus the 'indirect' GHG emission coefficient from Ecoinvent (see 7.3.1 for details). DEFRA (2010a) suggests that the 'international passenger rail' produces 0.017 kg of CO_2-eq. per 1 pkm, where the direct carbon footprint accounts for 0.015 kg and the 'indirect' contributes with 0.002 kg. This estimate is based on figures provided by Eurostar and some independent calculations carried out by DEFRA. Ecoinvent estimates the GHG emissions from two categories of long-distance passenger rail: 'Inter-City Express (ICE)' and 'long-distance train'. The background information states that the former category represents the German high-speed intercity trains while the latter is typical for Switzerland and includes a number of train types, namely Eurocity, Intercity, Interreg, Express, etc. The analysis of the total GHG emission factors indicates that the 'ICE' rail transport is over 7 times more carbon intense than the 'long-distance train' category (Table 8.4). The significant discrepancy is deemed to be due to the difference in fuels used for electricity generation in Germany and Switzerland. While most of the electric energy consumed in Switzerland is generated from nuclear and hydropower (Swiss Federal Office of Energy 2010) with consequent low direct carbon footprint, the Germany's electricity production still relies on carbon-intense coal (International Energy Agency 2011). It is argued that the carbon intensity of trains operated in France is similar to the carbon intensity of rail services in Switzerland. This is because the energy balance in Switzerland has a more distinctive share of renewables. Importantly, while the difference between the direct carbon footprints of international rail categories in the Ecoinvent database is significant, the discrepancy in estimates of the 'indirect' GHG emissions is only 15% (Table 8.4). The 'indirect' GHG emissions from the less carbon-intense Switzerland-based 'long-distance train' category of long-distance rail travel will be utilised for this case study.

Table 8.4. GHG emission factors for international (long-distance) rail transportation as suggested by Ecoinvent and DEFRA.

Method	Category name	Direct GHG emissions	'Indirect' GHG emissions	Total GHG emissions
		kg CO_2-eq. per 1 pkm		
DEFRA	International passenger rail	0.015	0.002	0.017
Ecoinvent	ICE	0.0526	0.0075	0.0601
	Long-distance train	0.00175	0.0065	0.0082
Hybrid	**Long-distance train**	**0.017 + 0.0065 = 0.0235**		

Thus, to obtain a hybrid GHG emission coefficient, the DEFRA total carbon footprint was summed with the 'indirect' GHG emissions from the 'long-distance train' train category estimated by Ecoinvent, i.e. 0.017 kg of CO_2-eq. + 0.0065 kg of CO_2-eq. = 0.0235 kg of CO_2-eq. per 1 pkm (Table 8.4).

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; for example, see Travel 55 (2010) for some existing holidaymaking options in Provence. As for independent travel, although the Eurolines provide regular scheduled services from London to Paris (for detailed schedules, see Eurolines 2011), there are limited opportunities to get by coach from

Paris to Marseille. Hence, this scenario assumes that the journey is made by an organised coach with two overnight stays in Paris. The driving distance from London to Marseille 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 airport travel in Southern France is not estimated as its contribution is deemed to be small. As tourists are assumed to live in Greater London, same argument has been applied to the GHG emissions from airport transport in the UK.

Scenario 5: Travel by coach and train.

The ‘combined’ scenario of traveling from the UK to Southern France by coach and train has also been considered. It is assumed that tourists take coach to get from London to Paris, stay in Paris overnight and then continue to Marseille by train. It is acknowledged that this is one of the least feasible scenarios of all scenarios considered. This is because traveling from London to Paris by train is significantly faster than by coach, i.e. 3 versus 8 hours, respectively. Cost is deemed to be the only factor which can determine decisions by tourists to use this scenario, as coach from London to Paris is often cheaper than train.

Scenario 6: 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 the least possible holidaymaking scenario from all alternatives reviewed, it is included into this analysis to demonstrate the profound carbon intensity of air travel interchange. The 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. 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. For better comparability, this scenario includes two overnight stays in Paris although it is acknowledged that such journey scenario can also exclude those.

There are a number of ‘combined’ scenarios which could have also been used for an analysis in this study. For example, train from London to Paris and then coach 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 unlikely in reality due to the cost, time and personal comfort factors.

8.3.3 Comparing the carbon performance of different travel scenarios

A comparative analysis demonstrates that, under the specified settings, going on holiday to Southern France by train, coach or a combination of train and coach are the most carbon-efficient travel options (Figure 8.3). 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 low/medium energy and carbon intensities compared to other transportation modes. Among these, rail is the least carbon intense scenario in the case 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. The combined coach + train scenario is suitable for environment-aware tourists with limited budgets.

Concurrently, Figure 8.3 shows that the air travel-based holidays generate the largest carbon impacts, especially when the air + air scenario is considered. This finding is in line with existing knowledge that flying is the most carbon intense means of travel. Importantly, the GHG emissions from the air-based scenario (with no intermediate change) are only circa 10 kg of CO_2-eq. (about 3%) higher than the carbon footprint from car. 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 are deemed to be the primary reason.

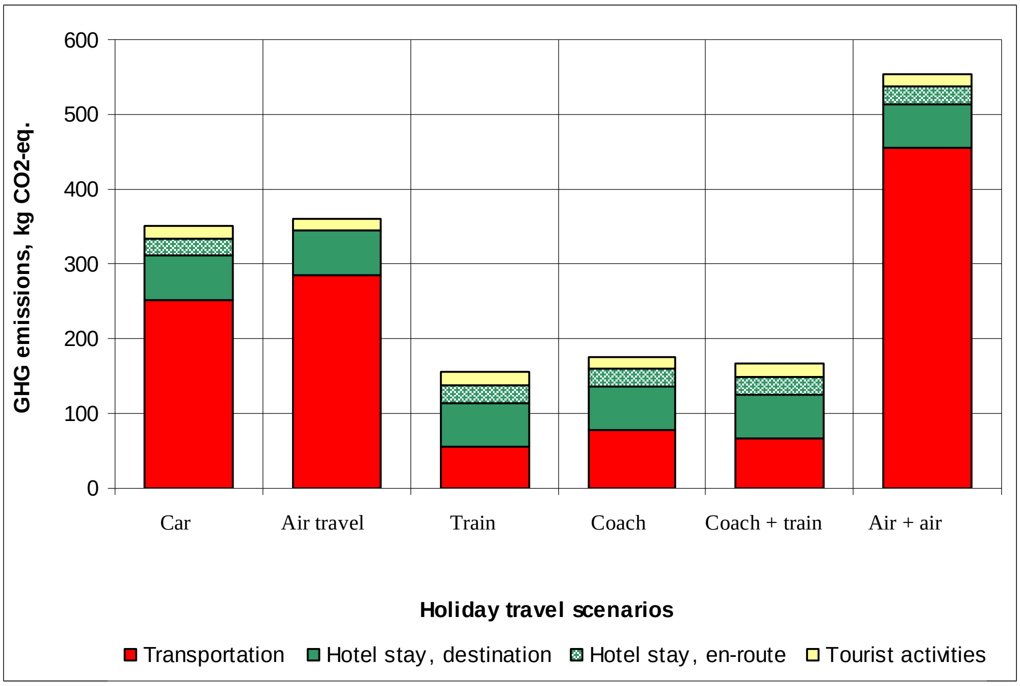


Figure 8.3. Carbon footprint from different holiday travel scenarios in Southern France, per tourist (length of stay = 7 nights). Source: Author.

When the holiday travel element of the carbon footprint for holidays in Southern France is analysed, the estimates suggest that transport holds a dominant share only in the car and air travel-based scenarios, i.e. 72% and 79% (82% in the case of the air + air scenario), respectively. In the coach scenario its contribution drops to 44%, while the role of the transport element in the rail and 'coach + train' scenarios is only 36% and 40%, respectively. This finding suggests that, if tourists and/or tour operators are willing to cut the GHG emissions from short-haul holidays based on air and/or car transport, switching to rail and/or coach is the easiest way to achieve significant carbon savings. 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 8.4 shows that the share of the transport element in the total GHG emissions from holidays reduces with a longer duration of stay at the destination. For example, if tourists stay in Southern France for 14 nights, transportation will then contribute 68% (74%), 61%, 33%, 30% and 26% to the air travel (air + air scenario), car, coach, coach + train and rail-based scenarios, respectively. The values will further fall, should more activities be undertaken by tourists at the destination and/or more intermediate hotel stays be organised en-route. The latter option is feasible as, for example, existing coach operators to Provence offer 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 also suggests that the non-transport elements of holiday travel can have a significant share in the total carbon footprint for short-haul holidays. It should not therefore be ignored in the GHG emission assessments of holiday travel and needs to be considered when developing the carbon mitigation measures for holiday packages.

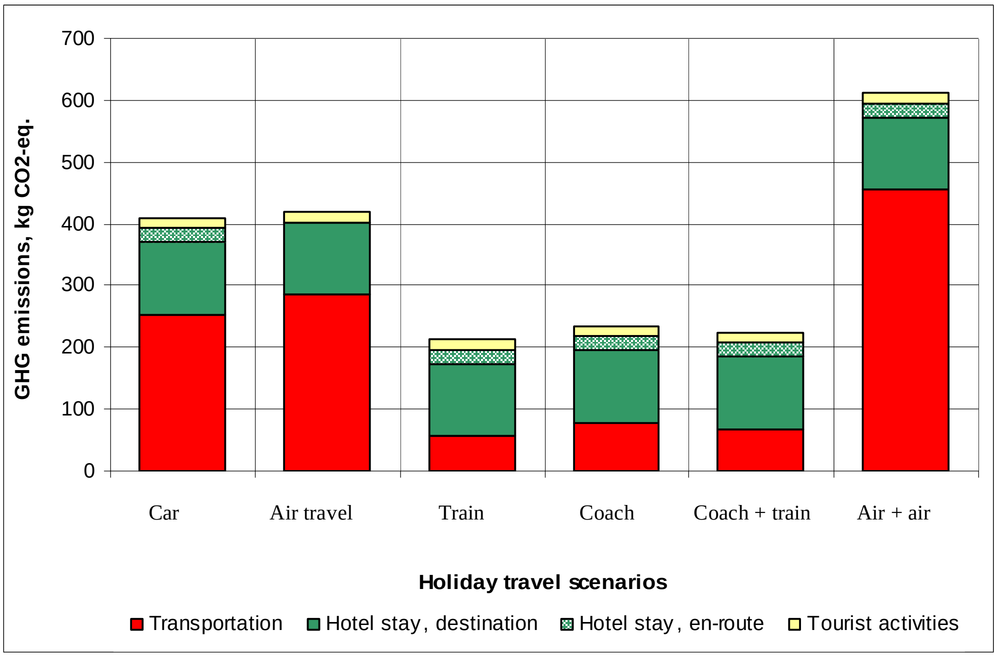


Figure 8.4. Carbon footprint from different holiday travel scenarios in Southern France, per tourist (length of stay = 14 nights). Source: Author.

When the estimates of the 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 8.5). However, 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 40-45% 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, 30-35%. This finding is in broad agreement with the literature which considers a longer stay at the destination more beneficial in the carbon footprint terms if the estimates are made on a daily basis.

Table 8.5. Estimates of the 'daily' carbon intensity for different scenarios of holidaying in Southern France, kg CO_2-eq. per tourist.

Scenario	Duration of stay at the destination	
	7 nights	*14 nights*
Car	50.2	29.3
Air	51.5	30.0
Air + air	79.1	43.8
Train	22.1	15.3
Coach	25.2	16.8
Coach + train	23.7	16.0

Figure 8.5 demonstrates that the 'indirect' GHG emissions make a profound contribution to the total carbon footprint from the reviewed travel scenarios. The air travel and car scenarios are characterised by the largest shares, i.e. 28% and 26%, respectively, while the other holidaymaking alternatives report lower, but yet significant, values of 18-21%. Most of the 'indirect' GHG emissions are attributed to the transport element. The largest contribution of the 'indirect' GHG emissions *within the transport element* of holiday travel is typical for rail (up to 40%), while the lowest is for coach (approximately 20%). 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 (Table 2.3). 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 when taking into account the 'indirect' carbon requirements. 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.

8.4 SUMMARY

This chapter has conducted a sensitivity analysis to better understand how changes in operational parameters of different holiday package elements (based on a survey of tourist activities) affect the magnitude of the total GHG emissions from the holiday package in the Algarve. The results demonstrate that flying distance is a parameter which makes the primary effect. Duration of stay and active participation in motorised tourist activities at the destination also play a role.

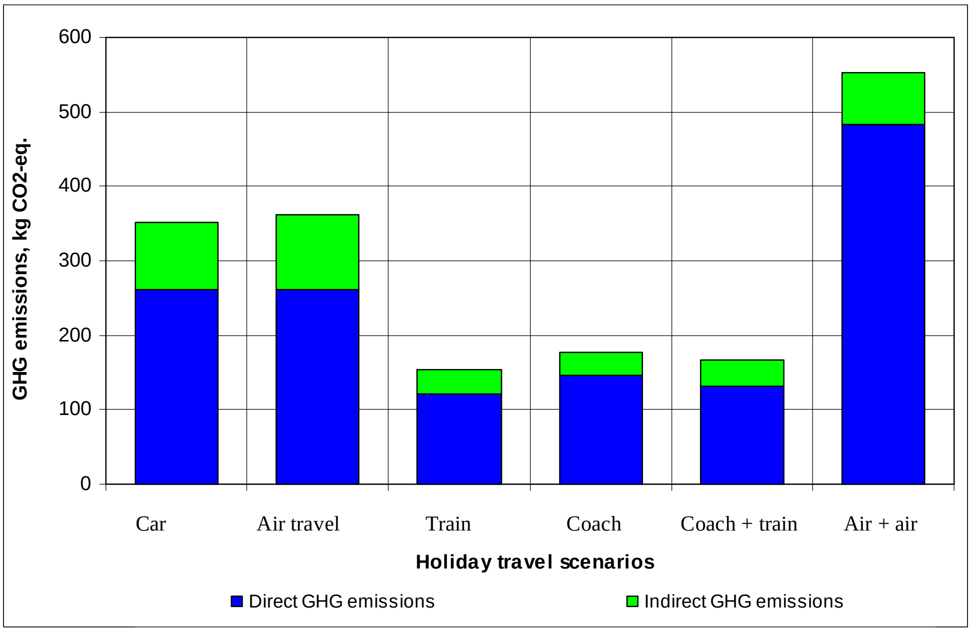


Figure 8.5. Direct and 'indirect' carbon footprints from different holiday travel scenarios in Southern France, per tourist (length of stay = 7 nights [20]). Source: Author.

A scenario analysis was performed to illustrate how the choice of transport to/from the destination affects the total carbon footprint from short-haul holiday travel. The results show that flying and car transport are the most carbon-intense means of travel while traveling to the destination by train and coach produce significantly lower amounts of GHG emissions. Importantly, it has been demonstrated that the non-transit elements of holiday travel can make a large contribution to the total carbon footprint from short-haul holidays, especially if tourists travel to the destination by land and stay there longer. Last but not least, the analysis has provided more empirical evidence that the 'indirect' GHG emissions have a profound share in the total carbon footprint from holidays. This suggests the necessity to account for the 'indirect' carbon requirements of tourism when conducting environmental assessments of its impacts and when developing carbon impact mitigation strategies.

[20] The estimate of the 'indirect' GHG emissions for 14 nights of stay is similar to 7 nights as the only difference is the additional 'indirect' carbon footprint from a longer hotel stay at the destination which is relatively low, i.e. 7.7 kg of CO_2-eq. per additional 7 nights.

CHAPTER 9. DISCUSSION AND CONCLUSION

9.1 INTRODUCTION

This study set out to enhance the quality of the methodological base for carbon footprint assessment in tourism by introducing a new method, Life Cycle Assessment (LCA), whose analytical accuracy and comprehensiveness are critically evaluated against existing alternatives. The application of LCA has demonstrated the significance of the 'indirect' GHG emissions which have never been holistically assessed in tourism. The appraisal of carbon impacts from a composite tourism product, a holiday package tour, has contributed to better understanding of the relative carbon intensity of different holiday travel elements in short-haul travel settings and under different transport-to-destination scenarios. The necessity to pay closer attention to this issue has been raised, but not consistently addressed in the literature. A critical review of advantages and drawbacks attributed to LCA over existing methodological alternatives for carbon impact appraisal in tourism has resulted in the proposal of a new, LCA-related method for more accurate and comprehensive assessments. Recommendations on how to improve the overall quality of carbon footprint appraisals in tourism and how to refine the effectiveness of existing techniques have been made. The research life cycle (logical research workflow) adopted in this study is outlined in Figure 9.1.

This chapter reviews the findings of the study and summarises its main conclusions and implications. The research objectives are re-visited and the degree of their fulfilment is critically analysed. The contribution of the study to knowledge is stated. The limitations of this thesis are evaluated and directions for further research are outlined.

9.2 REVIEW OF OBJECTIVES

1. *To critically evaluate the capability of the key techniques for environmental assessment of tourism impacts to provide accurate and holistic estimates of carbon footprint from tourism products and services;*

The analysis has shown that the potential of existing techniques to provide accurate and comprehensive estimates of the carbon footprint is limited. Despite a significant contribution of the tourism industry to the global GHG emissions, no universally recognised approach exists to specifically quantify the magnitude of tourism carbon impacts. The available appraisal methods have been developed outside of the tourism milieu; as a result, they lack understanding of the tourism-specific data requirements for holistic carbon footprint assessment and yet need to be adapted for successful application in the tourism context.

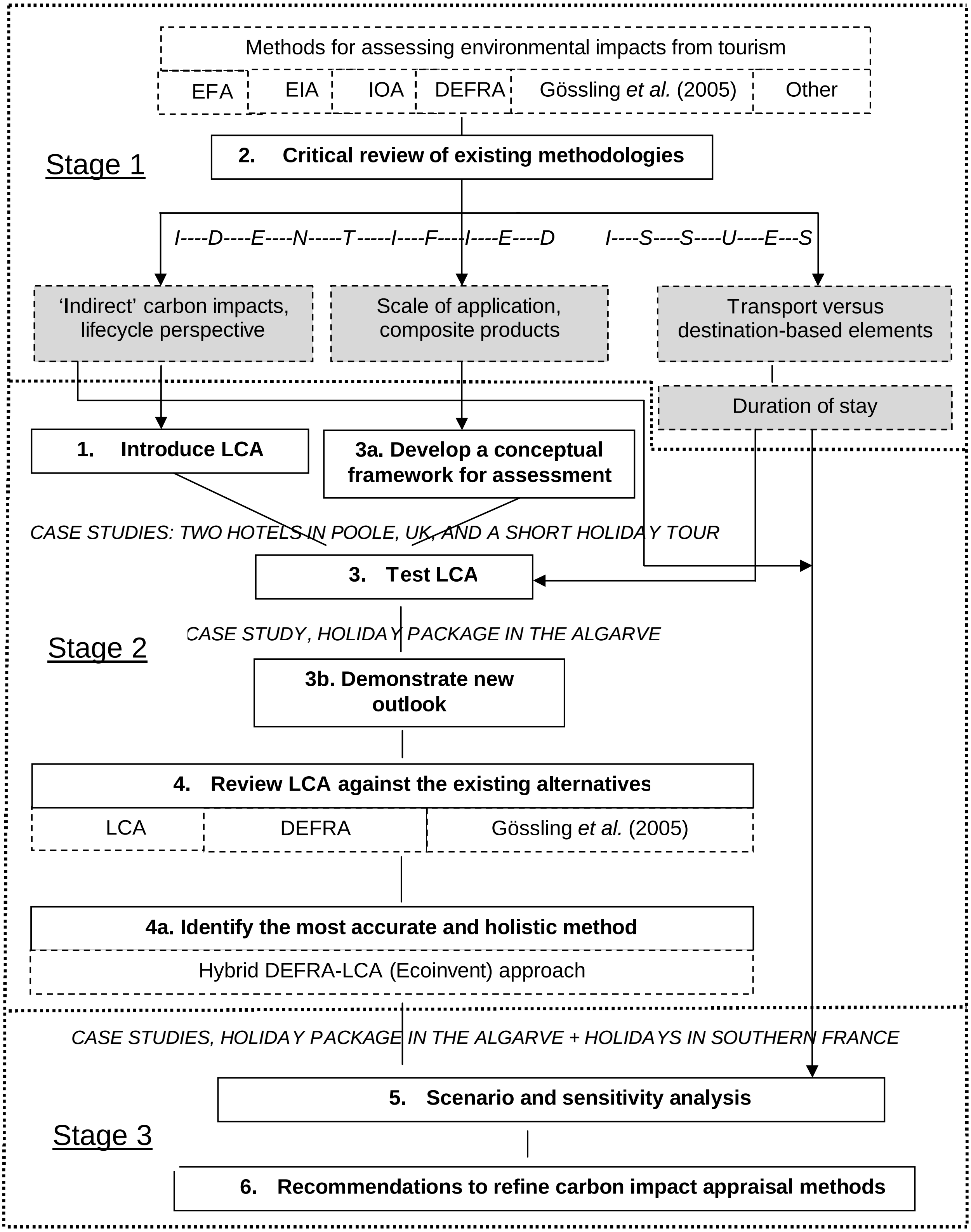


Figure 9.1. Logical research workflow (research life cycle).

A gap in addressing the 'indirect' GHG emissions from holiday travel has been identified. These arise at different stages of the lifecycle of tourism products and services and relate to the capital goods and infrastructure (see, for instance, Frischknecht *et al.* 2007a; Patterson and McDonald 2004). This 'indirect' carbon footprint can further be magnified by the supply chain. The evidence from the non-tourism sectors and recent large-scale, input-output economic-environmental tourism modeling has emphasized the significance of the 'indirect' GHG emissions from leisure-related activities and called for their integration into carbon footprint assessments of holiday travel. The current scope of carbon impact appraisal in tourism is however restricted to the direct GHG emissions only and needs to be extended to account for the 'indirect' carbon footprint, to provide more accurate and holistic estimates.

Further to the limited scope, an issue with the scale of application of carbon footprint assessments in tourism has been identified. The primary focus of existing studies is on the higher, 'macro' scale of the national tourism industries and its separate sectors, while the lower, 'micro' levels of specific tourism products, services and activities are less addressed (Peng and Guihua 2007). This is partially due to the problem with data collection, as the required data are better maintained and easier to obtain from the national or sectoral statistical databases (Bagliani *et al.* 2008). This macro approach clashes against the fundamental principle of sustainable development 'think globally, act locally' which advocates the necessity of pro-active environmental impact reduction measures at the lower, local scales. Furthermore, the implementation of any carbon mitigation measures is the responsibility of local stakeholders. To achieve effective reduction, the magnitudes of local carbon impacts need to be first established and understood.

Moreover, limited evidence of holistic carbon footprint appraisal of holiday package tours exists in the literature (Becken *et al.* 2003a). These tourism products are composed of a number of different elements. The composite structure suggests that holiday packages are located at the intermediate, 'meso' level in the tourism products and services hierarchy, i.e. between the national tourism industries and separate tourist activities. The absence of a solid conceptual framework for carbon footprint assessment of holiday packages, along with the attributed methodological difficulties of analysing such complex products, is the primary reason for the exclusion of holiday package tours from existing carbon impact assessments in tourism. As holiday packages remain to play an important role in the global tourism market, a reliable conceptual framework and rigorous assessment techniques for carbon footprint appraisal of composite tourism products have to be developed. Establishing accurate magnitudes of GHG emissions from specific holiday packages facilitates development of effective carbon abatement measures and enables design of more carbon-efficient tourism products. This would be useful for all tourism as such tourism products as independent holiday trips usually consist of the same structural elements as holiday package tours.

In addition to the limitations in scope and scale of application, the review has flagged up some controversy in the general understanding of the relative magnitude of carbon impacts from holiday travel. The transport (transit) element is a primary focal point of existing carbon footprint assessments (see, for example, Gössling *et al.* 2002; Gössling *et al.* 2005). This is because, generally, it produces the majority of the GHG emissions from a holiday package. There is however some empirical evidence to suggest that, in short-haul travel settings, the carbon contribution from the non-transport (destination-based) elements can also be significant. No detailed sensitivity analysis has been applied to better understand the relative carbon impacts among all the holiday package elements. More comprehensive scenario and sensitivity analyses of popular short-haul holiday packages are required to discover the major contributors to the GHG emissions they produce and to identify the most and the least carbon-efficient holidaymaking patterns. The popular practice that makes the 'by default' allocation of the primary carbon impacts from short-haul holiday packages to the transport element, with parallel disregard of the non-transport elements under the assumption of their negligible contribution, can overlook significant amounts of GHG emissions and lead to inaccurate conclusions.

Longer stay at a short-haul destination, for example, is an important factor to consider as it may dramatically affect the overall magnitudes of GHG emissions from holidays. Longer duration of stay is generally encouraged as the carbon impacts from the destination-based elements of holiday travel are often viewed as low while the overall eco-efficiency of longer stays can be high. However, there is indirect evidence in the literature that, under the short-haul travel settings, longer stay may result in significant amounts of GHG emissions, should tourists travel to the destination by overland transport, take active part in energy-intense activities and stay in old and energy-inefficient hotels (see, for instance, Becken *et al.* 2003a; Chenoweth 2009). This implies that the relative carbon significance of a transport (transit) element of holiday travel can be lower than traditionally accepted in analysis of certain short-haul holidays. Another critical issue which calls for a closer analysis is the 'daily' carbon intensity of holiday travel with different durations of stay at the destination.

The case study and scenario analysis employed in this thesis demonstrate the relative role of the transport and non-transport elements in the total GHG emissions from a standard short-haul holiday package. The study also shows how the relative and absolute carbon intensity of specific holiday travel elements change when the long-term stay and different transport-to-destination scenarios are considered. Comparative analysis of feasible travel scenarios may help develop more carbon-efficient tourism products (Becken *et al.* 2003a) and raise tourist awareness of the carbon impacts they impose (Tepelus 2005).

Sections of the literature review on the critical analysis of existing techniques for carbon impact appraisal in tourism and the methodological issues it has identified have been reported in a journal article (Filimonau *et al.* 2011a, see Appendix 2).

2. *To examine the potential of Life Cycle Assessment (LCA) for holistic appraisal of carbon footprint from tourism products, services and activities;*

The literature review has revealed limited evidence of the application of Life Cycle Assessment (LCA) in tourism, although it has long-standing traditions of use in the non-tourism fields. The major advantage of this technique is the capability to measure the 'indirect', lifecycle-related GHG emissions attributed to the capital goods and infrastructure. These have been estimated for a broad range of materials, products and services and summarised in the form of an extensive inventory database, Ecoinvent. As the literature demonstrates, there is a gap in establishing the magnitudes of the 'indirect' carbon footprint in tourism. The application of LCA can rectify this issue.

Despite the new outlook the LCA technique can bring to existing knowledge on carbon impacts from tourism, the application of LCA in the tourism sector is restricted to singular case studies. The detailed outcome of these studies is not publicly available; hence, no empirically supported judgments on the suitability of the LCA technique for the requirements of tourism carbon footprint assessment could be made. As tourism is a complex industry, the basic data requirements for lifecycle analysis of tourism products, services and activities needed to be evaluated and the routine data collection procedure had to be outlined. Hence, given the merits of LCA, there was a need to explore in more depth its potential for application in the tourism context. It was important to better understand if the methodological advantages of the LCA technique outweigh its drawbacks. These relate to often extensive data and labour requirements, costs of the Ecoinvent inventory database and limited practicability of some of the assumptions applied. The LCA technique itself can also benefit from testing in tourism as a new sectoral avenue for its application. Thus, extending the scope of LCA application to tourism is advantageous not only for tourism carbon footprint assessment, but also for the development of the LCA method.

Preliminary analysis of the Ecoinvent database and critical review of existing LCA-based studies focusing on leisure-related activities have shown that the Ecoinvent inventory is suitable for estimating the GHG emissions from tourist transport and a number of studies have already applied LCA for carbon impact assessment of leisure travel. The data required for conducting LCA of different transport means are fairly easy to collect and this may explain the popularity of the technique in the transportation field. The potential of Ecoinvent to address the other two fundamental elements of holiday travel, i.e. tourist accommodation and activities, has been found to be theoretically sufficient, but not yet investigated in practice.

To explore the capability of LCA for measuring the carbon footprint from tourist accommodation, a case study approach has been utilised where the GHG emissions from two hotels in Poole, UK, have been assessed. The case study has demonstrated that the application of a full-scale, original LCA to carbon impact appraisal of tourist accommodation is not feasible as it handles a number of environmental impact categories and requires extensive data collection. The Life Cycle Energy Analysis (LCEA) approach, a simplified derivative of LCA, has therefore been introduced and critically reviewed. LCEA focuses on energy use and consequent GHG emissions as the only measure of environmental impacts. It is an established tool for carbon footprint appraisal of commercial buildings; hence, it can be applied for carbon footprint assessment of tourist accommodation facilities. Importantly, the scope of LCEA can be extended to cover other elements of holiday travel.

Apart from evaluating the potential of LCEA for future application in the tourism carbon impact assessment field, the case study of two hotels in the UK has also served a piloting opportunity to test LCA assessment skills, better understand the Ecoinvent database and identify the basic data inputs required for holistic carbon footprint analysis of tourist accommodation. The outcome of the case study has been published in a journal article (Filimonau *et al.* 2011b, see Appendix 2).

To demonstrate how LCEA can be applied for estimating the GHG emissions from other elements of holiday travel, the technique has been employed for simplified carbon impact appraisal of a holiday tour from London to Poole. The outcome of the LCEA analysis for hotels in Poole reported in Filimonau *et al.* (2011b), Appendix 2, has been supplemented with the LCEA-based estimates of the GHG emissions from coach travel. The results of the LCEA analysis have been compared against the estimates produced by the key conventional methods for carbon footprint assessment in tourism. The outcome of this case study has been published in Filimonau *et al.* (2011a), Appendix 2. It has proven that LCEA is a feasible technique for assessing the carbon footprint from tourist transport and accommodation. Extending the scope of LCEA application, also for appraisal of the GHG emissions from another fundamental element of holiday travel, i.e. tourist activities, was further required. Objective 3 addresses this need.

The case study has revealed a discrepancy in measurements of carbon impacts as produced by different techniques for carbon footprint appraisal in tourism. This has emphasized the necessity of an in-depth analysis of the reviewed methodologies and the assumptions they are based upon, to better understand the causes and effects of the variance in estimates. This issue is discussed in objective 4.

3. *To provide empirical evidence of the applicability of LCA in the tourism context by performing holistic carbon footprint assessment of a short-haul holiday package;*

To demonstrate how a simplified derivative of LCA, LCEA technique, can be applied to carbon footprint appraisal of composite tourism products, a case study approach has been adopted to conduct holistic carbon impact assessment of a standard all-inclusive holiday package in the Algarve, Portugal. As holiday package tours are not established objects for impact assessment in tourism, development of a feasible carbon footprint appraisal procedure for these tourism products is required.

To develop a conceptual framework for holistic carbon footprint assessment of a composite tourism product, a holiday package tour

A holiday package is a composite product. It consists of the number of structural elements which can be aggregated into three main functional groups, i.e. transport, accommodation and activities. To estimate the total carbon footprint from a holiday package, these elements need to be first assessed separately. The element-specific GHG emissions are then summed to calculate the carbon footprint from each functional group. This will demonstrate the relative carbon significance of transport (transit) and non-transport (destination) elements of holiday travel. Evaluation of the element-specific relative distribution of carbon footprint within a holiday package outlines sectors where the primary carbon mitigation measures are necessary. Summation of the carbon impacts from all functional groups produces a total estimate of GHG emissions for the entire holiday package.

To assess the carbon significance of different holiday package elements, two types of primary data are required:

First, the basic operational data (operational parameters) determining the magnitude of the GHG emissions from specific tourism products, services and activities need to be retrieved. For coach travel these are represented, for example, by distance travelled, category of vehicle used, type and/or amount of fuel consumed and vehicle occupancy. The more operational parameters are known, the more accurate and holistic carbon impact assessment can be conducted.

Second, the carbon intensity coefficients attributable to each specific element of holiday package are required. These can be measured direct or extracted from the established GHG emission databases where the averaged, pre-measured values are available. The basic operational parameters affecting the magnitude of the carbon footprint for specific holiday package elements are then used to adjust the appropriate original GHG emission coefficients, to estimate the carbon impacts as approximate to the reality as possible. To calculate the carbon footprint from a specific holiday package element, the relevant adjusted carbon intensity coefficients are multiplied by the number of element-specific activities undertaken by tourists. This research has proposed a conceptual framework which outlines the determinant basic operational parameters. It has also critically evaluated existing databases of GHG emission factors required to conduct accurate carbon footprint appraisals of a holiday package.

Applying LCEA to a holiday package in the Algarve has demonstrated that, among its elements, those attributed to the accommodation and transport functional groups are the least cumbersome to assess. This is because most of the basic operational data required for carbon footprint analysis, such as types and amounts of energy and fuel consumed, categories of vehicles utilised, distances driven and the values of vehicle and hotel occupancy, can be obtained from a number of easily accessible, including secondary, sources. These sources are represented by providers of a specific service and/or activity (for example, hotel or travel agent), online distance calculation tools (Google maps) and/or promotional and marketing materials (holiday package brochures). For some elements of tourist transport, these basic data need to be supplemented with additional primary information collected from tourists. These supplementary data are required to adjust the original transport-specific GHG emission factors which are by default based on the averaged values. For example, factors such as vehicle category, fuel type and occupancy have been found to affect the carbon footprint from transportation to/from airport in the origin country. These variables differ from tourist to tourist while it is unlikely to obtain this information via a tour operator, or in secondary sources, as travel to/from airport in the origin country is usually not included into a holiday package. These data are therefore best retrieved first-hand from tourists. While less important for holiday packages based on air transport, where the carbon impacts from transportation to/from airport may remain in the shadow of the profound GHG emissions from flying, the effects of adjusting the carbon footprint from transport with the help of supplementary primary data may become more critical when tourists get to the destination independently like, for example, by train.

The case study has shown that the basic operational data required for holistic carbon footprint assessment of tourist activities are complex and diverse. In contrast to tourist transport and accommodation, they have never been and arguably cannot be averaged; hence, they are difficult, if not impossible, to retrieve from secondary sources. Direct communication with tourists is the only reliable method for gathering these data. Additional insights into activities undertaken by tourists at the destination can be obtained via empirical observations. It has been shown that the use of generic data from previous studies is not suitable to describe the case-specific tourist activities as this may hamper the accuracy, endanger the currency and question the representativeness of results. All this implies that surveys on tourist activities are required in order to collect basic information for reliable carbon footprint assessment of tourist activities as an element of a holiday package.

The absence of established GHG emission factors for the majority of specific tourist activities, attractions and entertainment options has been identified as another issue hampering accurate estimates. The carbon intensity of tourist activities varies depending on geography, size of facilities, type of equipment used and the number of participants. The GHG emission inventories do not specifically provide carbon emission coefficients for tourist activities; hence, direct measurements and/or the figures from the case studies reported in the literature are the only feasible source of information to fill this gap. This thesis has critically reviewed the estimates of carbon intensity for different tourist activities as proposed in the literature. It has identified some feasible carbon footprint values which can be employed in future carbon impact appraisals. The critical review of existing carbon footprint assessments of tourist activities conducted in this study has revealed the necessity of more in-depth research on the carbon intensity of popular tourist activities in different geographies, to establish some representative values for future appraisals.

To conduct a holistic assessment of tourist activities as an element of the holiday package in the Algarve, a tourist survey questionnaire has been developed. This questionnaire can be used as a basis for retrieval of the basic operational data on tourist activities in future carbon footprint assessments of composite tourism products. When supplemented with empirical observations, such surveys will provide the necessary basic operational data to make accurate estimates of GHG emissions from tourist activities. While the relative carbon contribution of tourist activities to the total GHG emissions from a holiday package is generally small, a survey on tourist activities enhances the accuracy and strengthens the comprehensiveness of analysis as it ensures that all elements of holiday travel are accounted for. The case study of a holiday package in the Algarve has shown, for example, that hotel stay in the origin country, which is not a traditional element of a holiday package, would have been omitted, should the survey on tourist activities had not been conducted. Hotel stay in the origin country can become an indispensible element of a holiday package for some tourists. Residents of such remote UK localities as Aberdeen flying to the holiday destination early morning from Glasgow are an example.

In addition to making the analysis more comprehensive, a survey on tourist activities enhances the overall quality of the study and ensures the estimates of carbon intensity attributable to other holiday travel elements are more approximate to the 'real life' situation. This is because it can also reveal the basic operational data on occupancies for different transportation modes, as employment of realistic occupancy values has been found a determinant factor affecting the accuracy of carbon footprint estimates from leisure transport. In the case of coach travel, for example, adjustment of the GHG emission factors using the realistic, rather than the 'by default' averaged occupancy coefficients, for the LCEA method (Ecoinvent database) has reduced the original GHG intensity factor for coach journeys by almost 50%. Finally, a survey on tourist activities is crucial when holidaymakers are expected to undertake a variety of energy-intense tourist activities at the destination as it has been shown that these may potentially have a noticeable contribution to the total carbon footprint from holiday travel. Although the carbon significance of specific tourist activities is low, the cumulative GHG emissions they produce can be large, should tourists stay at the destination longer and undertake a large number of the fossil fuel-based tourist activities. Objective 5 addresses this issue in depth.

To summarise, the case study of a holiday package in the Algarve has demonstrated that LCEA can be successfully applied for holistic carbon footprint assessment of holiday packages. The basic data requirements for analysis are similar to those imposed by existing methods; hence, no drastic alterations are necessary in the routine data collection. A conceptual framework for carbon impact appraisal of holiday packages proposed in this study helps better understand the basic data needs and develop more effective methods for data retrieval. It has been revealed that some improvements are necessary in the background assumptions employed by the LCEA technique to produce accurate and holistic estimates of the GHG emissions from tourist transport. These relate to the default vehicle occupancy values and distance definitions operated by this method and will be discussed in detail in Objective 7.

To demonstrate a new outlook LCA brings to carbon impact appraisal in tourism

Applying LCEA for assessing the carbon footprint from the holiday package in the Algarve also evaluates the advantages offered by a new technique to tourism carbon impact appraisal. A better understanding of the magnitudes of the ‘indirect’ GHG emissions is the area where LCEA can make a primary contribution. The case study has shown that the ‘indirect’ lifecycle-related GHG emissions play an important role in the total carbon footprint from the holiday package. The ‘indirect’ carbon contribution within the holiday package in Algarve has been estimated by LCEA as high as 20% of the total. The largest ‘indirect’ GHG emissions of 10-20% are attributed to tourist transport. Long-distance trains and air transport have the most significant ‘indirect’ carbon shares, over 50% and 20%, respectively. Tourist accommodation and activities are characterised by lower contributions, i.e. 5-10%. This finding indicates that the ‘indirect’ carbon impacts from tourism are significant and need to be integrated into future carbon footprint assessments.

This outcome of the case study suggests that the conventional estimates of carbon intensities for specific tourism products, services and activities need to be re-assessed. It is an established fact, for example, that flying generates large amounts of GHG emissions. This research has shown that the estimate of the carbon footprint from flying is incomplete and will be further enhanced, should the ‘indirect’ GHG emissions, also embodied in the capital goods and infrastructure of air transport, be added to the picture. The application of the lifecycle approach in tourism carbon footprint appraisal alters traditional understanding of the total magnitude of carbon impacts from popular tourism products, services and activities. More empirical evidence on the significance of the ‘indirect’ GHG emissions is required and this calls for a broader utilisation of the

LCEA method in tourism, to establish some representative values of the 'indirect' carbon footprint for popular tourism products, services and activities with given parameters.

4. *To perform a comparative analysis of LCA with existing methodological alternatives for carbon footprint assessment in tourism;*

This study has aimed to identify the method, or a combination of methods, for the most accurate and holistic estimates of GHG emissions from holiday travel. The carbon footprint from the holiday package in the Algarve has been assessed by applying existing methodological alternatives to the proposed new LCEA technique. The GHG conversion factors from DEFRA (DEFRA 2010a) and the method by Gössling *et al.* (2005) have been selected for analysis because the literature review identified these methods as the key existing approaches for carbon impact appraisal in tourism. The estimates of the carbon footprint from the holiday package in the Algarve produced by LCEA have been compared against the values generated by the selected alternatives. The discrepancies in estimates have been evaluated and the reasons for variance critically analysed.

The comparative analysis has shown that the LCEA technique produces the highest estimates of GHG emissions. These are on average 23% and 5% higher than the values from DEFRA and Gössling *et al.* (2005), respectively. This is primarily because of the 'indirect' carbon footprint arising from the capital goods and infrastructure, which are accounted for in its assessments, but excluded by other methods. If the 'indirect' carbon impacts are not taken into account, the method by Gössling *et al.* (2005) suggests the largest figures which are on the average 32% and 13% higher than the estimates from DEFRA and LCEA, respectively. The carbon impact assessment approach by Gössling *et al.* (2005) is based on simple, but dated and globally-averaged GHG emission coefficients. This has a clear effect on the overall accuracy of estimates. The lowest values of the carbon footprint from the holiday package in the Algarve have been generated by DEFRA (2010a). This method employs recent, predominantly UK-specific GHG emission coefficients which include the 'indirect' carbon impacts from fuel production but do not account for the 'indirect' carbon footprint from the capital goods and infrastructure. Compared to other methods, apart from addressing the 'indirect' capital goods and infrastructure-related carbon impacts, the LCEA technique is applicable to broader European geographies, but lacks regular updates.

The discrepancy in these estimates of carbon footprint has underlined the necessity to conduct an in-depth evaluation of the reviewed methods, to assess their advantages and drawbacks and to understand what factors affect the results. This should help identify the most accurate and cost-effective method for carbon impact appraisal in tourism. The critical review has shown that, despite the comprehensiveness of the LCEA approach and simplicity of the method by Gössling *et al.* (2005), the appraisal technique from DEFRA has a number of critical advantages and can arguably be a currently more appropriate technique in terms of the overall cost-effectiveness. This is due to the following reasons:

- The DEFRA database of GHG emission factors is free to access, annually updated and undergoes regular re-evaluations to account for the latest advances in transport and energy-generating technology. It is supplemented with detailed background information outlining the major assumptions employed for development of specific GHG emission values. Solid and regularly revised background data ensure that the GHG conversion factors from DEFRA model the reality with the closest degree of approximation.

- The GHG emission coefficients from DEFRA are easy to understand and user-friendly as all calculations are made in Excel which is supplied in a ‘ready to use’ form with all pre-defined values of carbon footprint enclosed. They can therefore be utilised direct, also by people with no or little scientific background in carbon footprint assessment. This has determined popularity of the DEFRA GHG emission spreadsheet not only with scientists, but also with managers and policy-makers.

- The GHG emission coefficients from DEFRA handle a wide range of product and service categories, including leisure transport and energy use in buildings. Moreover, they offer flexibility in estimates of specific carbon impacts. The carbon footprint from transport can, for example, be measured either on a ‘per vehicle km’ or ‘per passenger km’ basis. Although the potential of DEFRA to measure the carbon intensity of tourist activities is limited, this issue is typical not only for DEFRA, but also for alternative approaches to carbon footprint assessment in tourism. It can be partially resolved if reliable estimates of energy intensities for different tourist activities are borrowed from the literature and further converted into the associated carbon footprints using the country and energy-specific GHG emission factors from the DEFRA database.

- The extension of the application scope for the DEFRA GHG emission coefficients is envisaged in the future. It is expected to cover new regions and product/service categories, including those related to tourism.

- Since a 2010 update, the DEFRA database has become capable of estimating the 'indirect' GHG emissions arising from fuel production, transport and distribution, i.e. the fuel chain-related lifecycle carbon footprint, the area that has been excluded from previous carbon impact assessments in tourism.

The current shortcomings of the DEFRA method are the inability to address the non-fuel chain related 'indirect' GHG emissions, such as from the capital goods and infrastructure (i.e. the capital goods-related lifecycle emissions) and its primary focus on energy generation and fuel combustion in the UK. Despite the latter limitation, the evidence of the application of the DEFRA coefficients in other geographies also exists. Many online carbon calculators, for example, employ the GHG inventory from DEFRA to make the estimates of carbon footprint in countries outside of Europe. Furthermore, DEFRA is a popular carbon footprint assessment method in other European countries and Australia and New Zealand.

The method by Gössling *et al.* (2005) has been found least accurate. This is mainly because it employs dated global average GHG emission coefficients. Moreover, it is too generic, does not measure a full range of greenhouse gases, fails to account for any of the 'indirect' carbon impacts, and provides no aggregate background data which could be critically reviewed to assess the currency and study-specific methodological viability of the assumptions applied. The analysis suggests that the method by Gössling *et al.* (2005) should only be used when high accuracy estimates are not required and/or when other methods cannot be applied. It can, for example, be employed for rough carbon footprint assessment of tourism products, services and activities in developing countries as neither DEFRA nor LCEA have originally been designed to address non-European geographies.

The critical evaluation has identified that the LCEA method models the reality with an acceptable degree of uncertainty but the accuracy of its estimates varies from one holiday travel element to another. LCEA is accurate enough for measuring the carbon footprint from energy consumption in tourist accommodation facilities and most surface modes of transport. However, a number of methodological reservations exist when estimating the GHG emissions from air travel, especially within Europe (see Objective 6). Other important limitations of LCEA are the cost of the Ecoinvent GHG emission inventory database and restricted public access to background information which is only available to the licensed database users. This hampers critical independent review of the assumptions employed in its estimates. The clear advantage of this method is the capability to quantify the 'indirect' lifecycle-related GHG emissions, also stemming from the capital goods and infrastructure, as neither DEFRA nor the method by Gössling *et al.* (2005) can measure this contribution.

To propose the currently most accurate and holistic method for carbon footprint assessment in tourism

The critical review of the three methods has shown that, although LCEA reveals a new and important, but previously unexplored, dimension in tourism carbon footprint assessment by estimating the 'indirect' lifecycle-related GHG emissions, the practicability of its broad application in tourism is limited by a number of factors. Cost of the Ecoinvent database, irregular updates, limited access to background data and application of some ambiguous assumptions diminish the value of the LCEA approach. In contrast, these issues are less typical for DEFRA. Since the GHG emission factors from DEFRA are also imperfect as they exclude the 'indirect' non-fuel chain related carbon impacts from the capital goods and infrastructure, it is argued that the most accurate and comprehensive approach for estimating the GHG emissions from holiday travel is combination of the DEFRA and LCEA methods. Given a slightly higher overall accuracy of DEFRA over LCEA in estimating the direct carbon footprint, due to more frequent updates alongside with its free access and detailed background information, it is argued that the GHG emission factors from DEFRA should be used as a structural basis for this hybrid approach. DEFRA will provide comprehensive estimates on the direct and fuel-related 'indirect' lifecycle carbon footprint. It will be supplemented with the data from the Ecoinvent database which will address the 'indirect' lifecycle GHG emissions from the capital goods and infrastructure. The data from Ecoinvent can also be used to quantify the carbon impacts from energy use among tourist accommodation in some European destinations currently not covered by DEFRA.

This thesis has demonstrated how a new, hybrid approach can be applied to carbon footprint assessment of a holiday package. A comparative analysis against the original LCEA and DEFRA techniques shows that the estimates of the GHG emissions produced by the hybrid DEFRA-LCEA (Ecoinvent) method are on the average about 3% smaller than the figures suggested by LCEA and approximately 21% larger than the values from DEFRA. The small difference between the original LCEA and the hybrid DEFRA-LCEA approach is arguably attributed to a slightly higher accuracy and up-to-dateness of the DEFRA values for direct carbon footprint. The discrepancy between the original DEFRA and the hybrid DEFRA-LCEA techniques is due to the 'indirect' carbon impacts related to the capital goods and infrastructure which has been earlier measured by LCEA as equal to about 20%.

The application of a hybrid method has pointed out how simplified estimates of the direct and 'indirect' carbon footprint from holiday packages can be obtained. It is argued that, in the absence of the GHG intensity factors from the Ecoinvent inventory database, the estimates of the total, direct and 'indirect' carbon impacts inclusive, GHG emissions can be approximated and measured as

'Original estimate from DEFRA + 20%'

Given the high cost of the Ecoinvent database, it is argued that this approach may represent a simplified, but concurrently quick and scientifically vigorous method of appraisal of the total carbon footprint from holiday packages, especially for those with parameters similar to the ones considered in this study.

To summarise, it is argued that the hybrid DEFRA-LCEA method is currently the most accurate and holistic technique for estimating the GHG emissions from tourism. This is because it addresses the primary categories of the known direct and 'indirect' carbon impacts. The hybrid DEFRA-LCEA method demonstrates that the total, capital goods and infrastructure (estimated by LCEA) and fuel chain-related (estimated by DEFRA), 'indirect' GHG emissions from a holiday package may account for up to 25-30% of the total (see Figure 7.9), where air transport is a primary contributor (see 7.3.1). This finding reinforces the literature which has theoretically estimated, but never holistically assessed, the magnitude of the 'indirect' carbon impacts from different tourism products, services and activities as equal to 15-30% of the total GHG emissions (Table 2.3). This study has provided empirical evidence and more accurate assessment in support of such estimates, thus justifying their rationality.

5. *To understand what factors affect the total and relative magnitudes of carbon impacts from a short-haul holiday package by applying a sensitivity and scenario analyses;*

To contribute to better understanding of the relative carbon significance of different holiday travel elements under the short-haul travel settings and by applying the most accurate and holistic method for carbon impact appraisal in tourism, a comparative analysis of the GHG emissions produced by all functional groups of the holiday package in the Algarve has been conducted. The results show that tourist transport is responsible for the dominant share of carbon impacts, i.e. 80-85% on the average, where air transportation is a primary producer. This finding complements existing empirical evidence which recognizes the supreme carbon intensity of flying. Tourist accommodation generates the second largest carbon footprint, with the average share of 13-18%. The relative contribution of tourist activities is insignificant, i.e. on the average 1-3% of the total carbon requirements of the holiday package. This suggests that tourist activities are an element of the holiday package where the carbon impact mitigation is most ineffective. This finding largely complements the conventional wisdom.

Sensitivity analysis

To identify the key factors affecting the absolute and relative magnitudes of GHG emissions from the holiday package in the Algarve, a sensitivity analysis has been conducted. The average (baseline) tourist profile has been drawn from the survey sample whose carbon footprint has been assessed. The sensitivity of the basic parameters attributed to the baseline profile and related to different elements of the holiday package has been tested by applying alternative scenarios attributable to other sample respondents. The deviations from the averaged carbon footprint have been monitored.

The results demonstrate that the distance flown to/from the holiday destination makes the largest effect on the GHG emissions from the holiday package. The carbon footprint grows proportionally with increase in the distance traveled, i.e. increasing distance by approximately 25% brings about the 20% rise in total GHG emissions. This finding is in line with evidence from the literature which considers distance as a primary factor determining the overall carbon footprint from holidays based on air transport.

Duration of hotel stay at the destination affects the carbon impacts from the holiday package in the Algarve. Double length of stay increases the carbon footprint by circa 10%. Given that the relative growth in GHG emissions related to doubling length of stay is low compared to the carbon footprint from transportation to/from the Algarve, the study adds weight to the view that longer stay holidays are more eco-efficient when the carbon impacts are estimated per ‘guest night’. The increase in GHG emissions with a longer stay is logical while in-depth research is yet required to establish more accurate magnitudes of its relative contribution to popular holiday packages with different parameters. Importantly, the value obtained in this case study can be an underestimate of average as the reviewed hotel is characterised by a higher energy-efficiency.

Tourist activities can also enhance the carbon intensity of the reviewed holiday package. When tourists take active part in fossil fuel-based activities, the total GHG emissions of holidays may grow by as much as 7%. This finding clashes against the literature which considers the carbon impacts from tourist activities as marginal. This study has shown that the effect of active participation in tourist activities at the destination can be more profound than traditionally accepted. This finding is interesting, given that the holiday package under review is based on air travel with consequent large carbon footprint from a transport element of holiday travel.

Finally, distance driven and means of travel to/from airport in the origin country are factors which can magnify the carbon footprint from the holiday package in the Algarve by 5%. This finding emphasizes the important role played by the choice of transport to/from airport in the total GHG emissions from the holiday package for tourists residing remotely from the airport.

Among other parameters, the sensitivity analysis has tested the effect of estimating the GHG emissions on a 'net' basis. The 'net' carbon footprint is more appropriate for assessment as it accounts for the carbon impacts which tourists had mitigated or, vice versa, enhanced by not having stayed in the origin country. The analysis has shown that the total GHG emissions from the survey sample drop, on average, by 9%, should the estimates be made on the 'net' basis. This finding suggests that future carbon impact appraisals of holidays should adapt the 'net' approach due to its higher methodological rationality.

The primary drawback of this sensitivity analysis is the limited representativeness of its outcome. Generalizations for other holiday packages should be made with caution. Despite this limitation, the analysis results are useful for design of a holiday package in the Algarve with less carbon-intense structural elements. The outcome of the sensitivity analysis should also help tourists make informed decisions about the carbon impact that the settings of the holiday package they choose have on the environment.

Scenario analysis

To better understand how the absolute carbon footprint from a holiday package alters and how the relative carbon intensity of the holiday package elements varies if alternative methods for getting to/from the destination are considered, a scenario analysis of different transportation options has been conducted. As flying is the only feasible mode of transport from the UK to the Algarve, an alternative holiday destination in Southern France, which can be easily reached by surface transport, has been selected for critical evaluation. The characteristics of the carbon footprint attributable to tourist accommodation and activities within the reviewed holiday package in the Algarve have been projected onto the alternative destination.

The results demonstrate that holidaymaking in Southern France based on air transport generates the largest carbon footprint while traveling to/from the destination by train and coach produce the lowest amounts of GHG emissions. The carbon intensity of the personal car-based holidays has been found to be surprisingly high and comparable to the carbon impacts from the air transport-based holidays. This finding provides additional evidence to existing knowledge that flying and driving a car are the least carbon-efficient modes of travel.

The ‘indirect’ GHG emissions from holidaymaking in Southern France have been measured as high, ranging from 18% (coach-based scenario) to 28% (flying-based scenario). The transport element of holiday travel is responsible for the largest contribution. This further emphasizes the necessity to integrate the estimates of the ‘indirect’ carbon impacts into carbon footprint assessment of holidays, especially those with an extensive transportation element.

The analysis of the relative carbon impacts from the holiday travel elements has indicated that tourist transport holds a dominant share of over 70% of the total GHG emissions in the air transport and personal car-based scenarios. Importantly, the carbon contribution of transport reduces to about 40% for train and coach. This finding implies that the profound reduction in the carbon footprint from holidaymaking in Southern France can be achieved simply by switching from the most carbon-intense modes of transport, i.e. flying and personal car, to the ‘greener’ alternatives, i.e. train and coach. This solution is effective and does not require any changes at the destination. Given that traveling from the UK to France by train is a fast and financially feasible option, the analysis has outlined possible directions for design of more carbon-efficient holidaymaking opportunities for British tourists in Southern France.

The relative carbon significance of the transport element further reduces when a ‘long stay at the destination’ scenario is considered. The transport element of holidays in Southern France accounts for 30% and 65% of the total GHG emissions in the train and air transport scenarios, respectively, if 14 days, instead of the baseline 7 days, duration of stay is applied. This finding supports the indirect evidence from the literature that, under certain short-haul travel settings, the relative carbon intensity of the transport (transit) elements of holiday travel can be outweighed by the GHG emissions generated by the non-transport (destination) elements.

Importantly, the contribution of a non-transit element of holidaymaking in Southern France will be larger, should the higher occupancy coefficients be employed for analysis of air travel. Although the occupancy factors used in this study are high, i.e. 70-82.4%, depending on the method, it is argued that they cannot still adequately represent the 'real-life' occupancies for charter flights in high season where the values of 85-90% are not uncommon (Mounser 1996). If the higher occupancy factors for air travel had been employed, the carbon footprint from air transportation per passenger km would have become smaller. This implies that the share of the transit element of holiday travel would have been further reduced, while the share of a non-transit element would have increased.

Furthermore, the contribution of the non-transit elements of holiday travel to its total GHG emissions would have been higher, if the analysis had been based on an older, less energy efficient, non-ecolabeled hotel, hotel with full-season operations and/or hotel using more carbon intense energy carriers for heating (for example, electricity). It is argued that the characteristics of the reviewed hotel in the Algarve do not represent the most typical hotel which many holiday packages can be based upon. Hence, the carbon footprint from tourist accommodation calculated in this study can be an underestimate compared to the GHG emissions produced by a more typical hotel. This has reduced the relative share of a non-transit element of holiday travel in its total GHG emissions.

Importantly, the previously demonstrated significance of the 'indirect' GHG emissions can also have important implications for estimating the relative carbon intensity of the holiday travel elements. This is because air transport is responsible for a dominant share in the total 'indirect' carbon footprint from holiday travel and the DEFRA-LCEA method estimates both, direct and 'indirect', carbon impacts. The relative share of flying in the total carbon footprint would have therefore been lower, should the estimates of its carbon impacts have been made on the basis of the 'direct' GHG emissions only, which is currently a common approach to carbon footprint assessment in tourism.

Likewise, the life cycle-related 'indirect' GHG emissions embodied in the hotel building, furniture and equipment have not been included in carbon footprint estimates of the destination-based elements of the holiday package in the Algarve due to the lack of data. If these are taken into account, the relative carbon significance of the destination-based part of holidays will grow.

This holistic analysis of the relative carbon significance of the holiday travel elements has important policy-making implications. This is because to-date, a transit element of holiday travel has been traditionally considered as a primary target for carbon footprint mitigation in tourism. While this study to a large extent reinforces this standpoint, it has also shown that, under certain travel settings, i.e. a short-haul holiday destination, travel by overland public transport and long duration of stay, the carbon significance of the non-transit element exceeds the transit element and should not be ignored when developing the carbon impact abatement measures. The value of this finding is further emphasized by some documented evidence that the destination-based elements of holiday travel may have a higher carbon footprint reduction potential compared to the transit element. This is predominantly because a broader range of affordable mitigation opportunities of both a technical and socio-economic nature exists for hotel managers, local transport operators and tourist activities providers at the destination. The carbon abatement potential of a transit element is significant in theory but often restricted in practice because of a number of technological and financial constraints. Thus, the non-transit element of holiday travel must be an equally important carbon footprint mitigation target, so more attention needs to be paid to the non-transit element in carbon impact appraisal of holiday packages as it can make a noticeable contribution to the total GHG emissions.

Lastly, when the GHG emissions associated with different durations of stay in Southern France are estimated per 'guest night', the analysis shows that a longer stay is 30-45% less carbon intense than a shorter stay. The study has thus added more empirical evidence to the conventional wisdom that a longer stay at the destination is more carbon-effective than a shorter stay when the estimates of GHG emissions are made on a 'guest night' or 'daily' basis.

6. *To propose measures for refinement of the reviewed methodologies for carbon impact assessment to enhance the effectiveness of their application in the tourism context;*

The critical review of the key methods for carbon footprint assessment in tourism has revealed a number of issues which affect the quality of appraisals. These hamper successful application of the reviewed techniques in the milieu of tourism carbon impact appraisal and obstruct the accuracy of produced estimates.

Background data and assumptions

The primary problem stems from the failure to disclose background data and explain the assumptions applied for estimating the GHG emissions from specific tourism products, services and activities. This information is usually summarised and discussed in the supporting literature which, in the case of the reviewed methods, is not always openly available (for example, the LCEA method) or consists of a number of unconsolidated separate sources, also produced in languages other than English (for instance, the method by Gössling *et al.* 2005). The unrestricted access to background data is essential for a quality analysis as all assumptions made when estimating the GHG emissions need to be thoroughly reviewed to assess their applicability to each specific case. The critical review of background information helps better understand if the assumptions applied can be used 'unchanged' or whether modifications are required to adapt the 'by default' suppositions for the requirements of a specific example.

The issue of constrained access to background data is of less importance to professional researchers as they are accustomed to data retrieval from the literature. The absence of explicit background information can however create significant problems for users with limited time and experience in data procurement, such as, for example, tourism managers and policy-makers. It is argued that all background data and major assumptions employed by the methods for carbon impact appraisal need to be aggregated and well presented in an open-access support document, an approach similar to the one adopted by DEFRA. This recommendation is in line with the data quality compliance requirement adopted by the PAS 2050 standard for holistic carbon accounting and reporting.

Occupancy and maximum load factors

The vehicle occupancy values and the maximum load factors, for example, have been found to significantly affect the outcome of the GHG emission estimates for transport; hence, the default values of carbon footprint assigned by the carbon impact appraisal methods to specific transport categories need to be known. A lack of access to background information on the default occupancy and maximum load factors may lead to miscalculations of the actual carbon footprint. Moreover, this also hinders any consequent comparison, should multiple methods be applied for a comparative analysis of results. For example, the difference in assumptions on vehicle occupancy and maximum load factors has been identified as a primary reason for the inter-methodological variance in the original estimates of the GHG emissions from coach travel for the LCEA and DEFRA methods. If the vehicle occupancy and the maximum load values are known, the estimates of carbon intensities can be re-evaluated and, if necessary, modified to improve their compatibility to the modeled reality, thus enhancing the accuracy of carbon footprint assessments. The estimates can also be reduced to a common denominator, should varied assumptions be employed by different methods, thus decreasing the discrepancy in results and facilitating comparison.

Furthermore, as occupancy is a determinant factor for accurate estimates of GHG emissions from transport, some of the default occupancy values proposed by the reviewed methods for carbon footprint assessment of leisure transport need to be re-visited as they are often not suitable for analysis. This study has shown, for instance, that the default occupancy factors for coach transport employed by DEFRA and LCEA are too low for measuring the GHG emissions from coach-based airport transfers and guided tours where higher occupancy values are more typical. To avoid miscalculation of the actual carbon impacts, the assumed original occupancies need to be clearly stated as they can be then modified to account for the 'real life' situation. A survey on tourist activities helps obtain realistic occupancy values by asking holidaymakers to specify the occupancies in transport modes they have used.

Given that occupancies for traditional scheduled and leisure-related (i.e. airport transfers, excursions, organised coach tours) coach trips differ, it is argued that a new category of 'coach transport for leisure purposes' and/or 'coach transport to airport' needs to be included to the GHG emission inventories used by existing methods for carbon footprint assessment. This should enhance the effectiveness of their application in the tourism domain. More experimental research on standard coach-based airport transfers and guided coach tours is required to obtain reliable occupancy values, maximum load factors and GHG emission estimates.

Definitions of travel distances for air transport

This study has also shown that the definitions of flight distances, with consequent assumptions on aircraft type, capacity and occupancy, can make a profound impact on the estimates of GHG emissions from holiday travel. This issue is of special relevance to short-haul air travel as the reviewed methods employ different definitions of short-haul flying distances. LCEA classifies all flights with one-way distance of up to 500 km as short-haul, while DEFRA categorizes these flights as domestic. In contrast, DEFRA assumes that short-haul flights have the maximum one-way distance of 3700 km. These assumptions affect the selection of a suitable aircraft category for serving the appropriate travel distances, with consequent variations in fuel consumption rates and releases of GHG emissions.

The aircraft selection is further linked to the maximum load and average occupancy factors which, as shown earlier, make a dramatic effect on the final values of an individual carbon footprint. The result of discrepancy in definitions for short-haul air travel is that the carbon intensity of short-haul European flights from LCEA, if the default definition is employed, is circa 1.5 times higher than the carbon intensity of short-haul inter-European flights from DEFRA. This implies that the inter-methodological harmonisation is required in distance definitions of air travel which should facilitate a comparative analysis and produce more realistic assumptions on the average occupancy values employed by the different methods for flights within specific flying ranges. Again, the disagreement on the definitions of travel distances and occupancy factors also indicates that all assumptions made by the methods for carbon footprint appraisal need to be thoroughly justified, aggregated in background literature and placed in the public domain. Finally, this finding indicates that the LCEA method needs to revisit its classification of short-haul flights in Europe as the definition it currently employs is likely to result in overestimated carbon footprints, should it be applied ‘by default’.

Application of a radiative forcing (RF) coefficient

The issue of the application of a radiative forcing (RF) coefficient has been identified. Currently, there is no agreement in the literature whether or not it has to be utilised for carbon footprint assessment of air travel, especially for regional and some short-haul flights (Berners-Lee *et al.* 2011). Moreover, the magnitude of a RF factor is also controversial. As a result, the reviewed methods handle a RF coefficient in different ways: while LCEA does not use any RF factor at all and DEFRA recommends, but does not apply it, the method by Gössling *et al.* (2005) includes a default RF coefficient of 2.7 to all estimates. The sensitivity analysis has shown that this could have resulted in the overestimation of the carbon intensity of the holiday package in the Algarve by 130%. It is therefore argued that a RF factor should not be employed direct, but for a sensitivity analysis only; moreover, it is important that the background literature accompanying the methods for carbon footprint assessment contains more information on the RF effect, the ranges of its magnitude and its implications for the GHG emission estimates. This will give researchers flexibility in decision of whether or not to include the RF effect to analysis, an approach adopted by some carbon calculators.

The recommendations outlined above are based on the critical review of the three methodologies for carbon footprint assessment. The implementation of these proposals should facilitate broader application of the reviewed techniques in tourism and/or make researchers aware about the necessity to address some critical issues related to their successful application.

9.3 CONTRIBUTION OF THE STUDY TO KNOWLEDGE

This thesis makes several contributions to original knowledge and these are briefly presented in Figure 9.2.

Extended empirical contribution

The study complements the research on assessment of environmental impacts from tourism, focusing on the contribution made to the global GHG emissions by popular tourism products, such as holiday package tours. A new dimension in the GHG emissions from tourism products and services, i.e. 'indirect', lifecycle-related emissions from the fuel chain, capital goods and infrastructure, is investigated and its importance demonstrated in practice by estimating the direct and 'indirect' carbon impacts from a holiday package in the Algarve, Portugal. The findings suggest that current estimates of the carbon footprint from tourism are likely to be underestimates as the 'indirect', lifecycle-related GHG emissions can be as high as 30% of the total. Moreover, the study provides new evidence on the carbon intensity of different holiday travel elements in analysis of short-haul holidays. This further contributes to the discussion on the absolute and relative carbon significance of the destination-based versus the transport-based elements and justifies the necessity of more careful consideration of the element-specific distribution of GHG emissions within short-haul holidays.

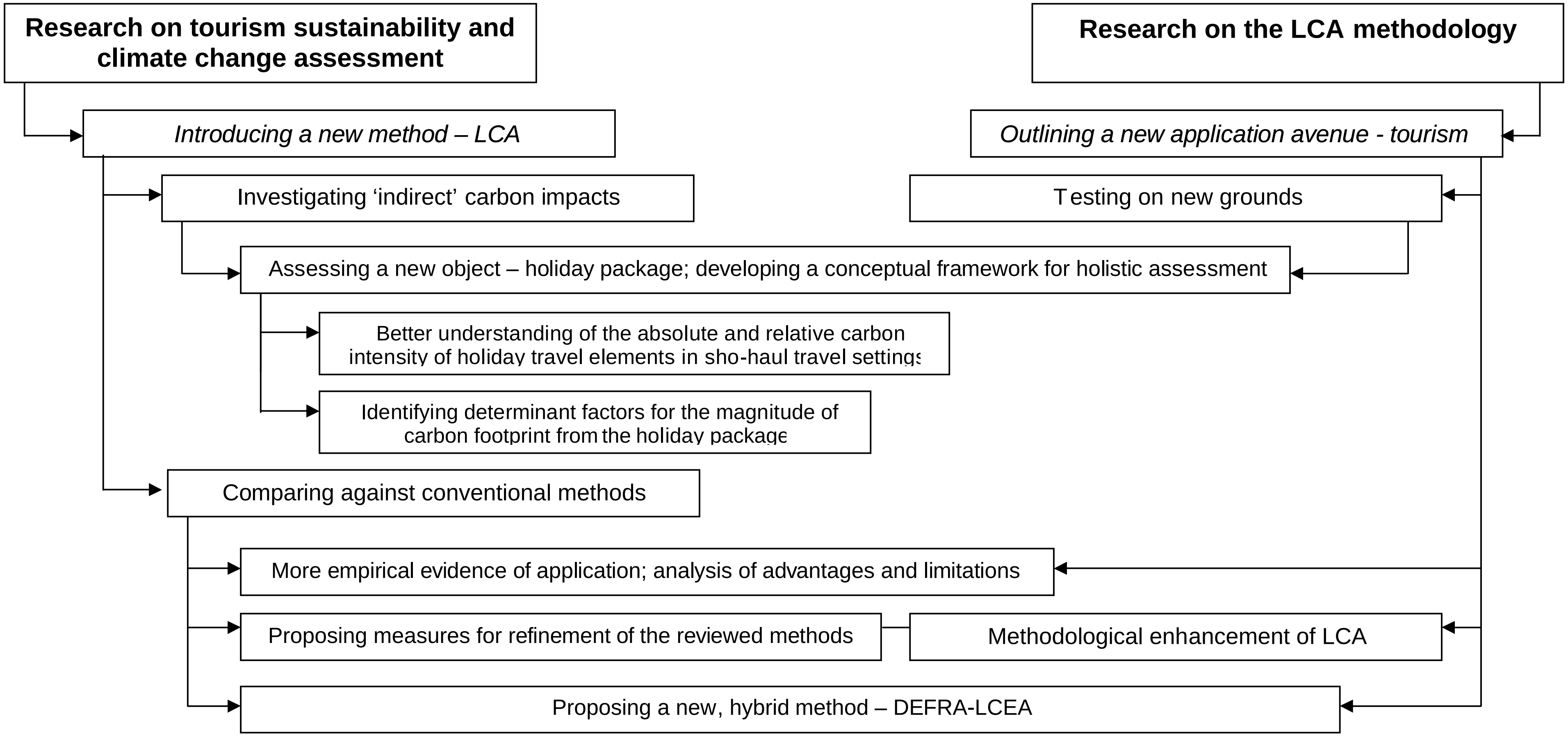


Figure 9.2. A graphical representation of the contribution to knowledge.

Methodological contribution

Responding to the call from the literature which emphasizes the necessity to develop new, more advanced techniques for carbon impact appraisal in tourism, this study introduces and tests a new method, Life Cycle Assessment (LCA), for holistic appraisal of carbon footprint from holiday travel. A critical review of the new technique against existing alternatives is carried out to investigate advantages and drawbacks of the reviewed tools. The most accurate and holistic technique is identified and the feasibility of its application is tested on a practical example. Measures to improve the reviewed methods for more effective application in the tourism domain are proposed.

Theoretical contribution

The appraisal of carbon impacts in tourism is enhanced by introducing a new, more advanced technique, comparing it against the conventional alternatives and proposing a tool for currently the most accurate and holistic assessments. A conceptual framework for holistic appraisal of composite tourism products is developed. The data requirements and methods for basic data collection required for assessment of GHG emissions from holiday package tours are outlined and assessed.

Practical contribution

The study critically evaluates the carbon efficiency of different scenarios for holidaymaking in Portugal and France to demonstrate how scenario and sensitivity analyses can be applied for design of 'greener' holidays. Suggestions are made on how to improve the carbon efficiency of holidaymaking. The review of the key methods for carbon impact appraisal in tourism provides a critical assessment of their major advantages and limitations. This highlights the areas within tourism where the application of specific techniques is more beneficial and/or where they need to be applied with caution.

The targeted audience for this study is represented by, but not limited to:

1) Tourism and environmental management academics who are introduced to a new method for holistic assessment of carbon impacts from tourism and to the areas where this method can contribute with new, valuable knowledge;

2) Tourism businesses who can now (by applying a new method) estimate the magnitudes of the carbon impacts associated with their products, services and activities with a higher accuracy, and in more detail. This can help to design more carbon-efficient products, work out more effective carbon mitigation measures, establish a ‘greener’ image, and gain market advantages;

3) Tourism and environmental policy-makers who gain access to more accurate and holistic estimates of the carbon intensities for specific tourism products, services and activities. Better understanding of the ‘indirect’ carbon impacts from different elements of holiday packages can help in developing more effective carbon abatement strategies;

4) Tourists and general public who can now better understand the significance of the carbon impacts from the holidays they undertake which in turn may facilitate pro-environmental behavioural changes.

This study has enabled the preliminary construction of a hierarchic list of the holiday travel-related factors which should be addressed to mitigate the carbon impacts from holidays (Table 9.1). While it is not a purely scientific but rather a schematic list, it can help tourism businesses better understand how different aspects / factors of holiday travel affect the magnitudes of GHG emissions from their products. This in turn should help the industry identify the areas for intervention (given the volume of resources available) and/or develop viable carbon footprint mitigation measures and strategies. This schematic list can also be used by tourists, to better understand the carbon intensity of their holiday choices, and by policy-makers, to plan more effective carbon impact reduction measures in the tourism domain.

9.4 LIMITATIONS OF THE STUDY

The limitations of this study have been acknowledged and thoroughly reviewed throughout the thesis. However, there are a few more limitations which need to be considered. These are as follows:

The standard holiday package in Portugal whose carbon footprint has been holistically assessed in this study is based on HV Algarve resort. It is a new build constructed according to the latest insulation and energy-saving technologies whose achievements in energy conservation have been recognised by the Travelife Green Tourism award.

This implies that the estimates of carbon impacts attributable to the tourist accommodation element of the holiday package in the Algarve are arguably lower than the GHG emissions from more traditional hotels which can be older and less energy-efficient. This means that the assessment of the carbon footprint from the tourist accommodation element of the holiday package obtained in this study is likely to be an underestimate when applied to analysis of a more 'typical' holiday package tour. This suggests that the appraisal results need to be interpreted with caution and calls for more research on carbon footprint assessment of traditional, non-ecolabeled hotels as these are more representative to the mainstream holiday travel.

Table 9.1. Schematic list of potential carbon footprint mitigation opportunities for holiday packages

Aspect / Factor	**Example (relative magnitude of carbon impacts)**	**How can it be addressed by a tourism business?**	**Relative effectiveness of carbon mitigation**
Modal shift in *transportation to/from the destination*	Air > car > coach > train	Research the feasibility of transport alternatives to the holiday destination	***Maximum***
Reduction of *travel distance to/from the destination*	Algarve > Southern France > Normandy	Research the feasibility of alternative holiday destinations located closer to the UK	
Stay in a *more energy-efficient hotel*	Standard hotel > Ecolabeled hotel	Demand better energy performance from contracted hotels at the destination / Demand eco-certification from contracted hotels	
Participation in *less carbon-intense tourist activities* at the destination	Jeep safari / car rental > boat cruise > theme park > visit to the beach	Encourage less carbon-intense tourist activities / Organise transport for tourist activities to achieve higher occupancies	
Modal shift in *transportation to/from the airport* in the UK / Modal shift in transportation to /from the airport at the destination	Car > taxi > bus > coach / train	Encourage travel by public transport (UK) / Organise airport transfers by train/coach, also with higher occupancies	***Minimum***

Another limitation of this research relates to the method of scenario analysis applied to the case study in Southern France. The selection of alternative travel scenarios used for comparison in this study is rather subjective; moreover, it does not cover a *full* range of possible realistic scenarios for holidaymaking in Southern France as these are difficult to predict (i.e. travel behaviour varies from individual to individual), may contain multiple elements (i.e. minor tourist activities not accounted for in this review), depend on different factors (i.e. weather, budget) and can therefore be of infinite order. Moreover, the scenario analysis is based on a static model. It excludes effects of many potential changes in the system under review like, for example, lower/higher occupancies in public transport at different times of day which may have significant impact on the carbon footprint.

9.5 UNRESOLVED ISSUES AND SUGGESTIONS FOR FURTHER RESEARCH

This study has outlined an approach to holistic assessment of carbon footprint from a complex tourism product, a holiday package tour. The primary aim was not to measure the GHG emissions with the highest degree of precision, but to develop a methodology to show how accurate assessments can be made in the future, which data are required for a comprehensive analysis and what factors may affect the accuracy of results. As a single case study, the findings from this review represent limited value as they cannot be statistically generalized. Some holiday packages may have similar carbon footprint patterns, while others may demonstrate considerable differences. This implies that the results of this study cannot be directly applied for comparative research of holiday packages with properties different from the ones considered in this study. Therefore it is recommended, on the basis of the conceptual framework proposed in this work, to carry out further carbon impact appraisals based on a hybrid DEFRA-LCEA methodology for holiday packages from different categories, durations of stay and tourist destinations to establish some representative standards for holiday package tours with given parameters.

Provision of reliable estimates of carbon intensity for tourist activities has been identified as an issue affecting the overall comprehensiveness of carbon footprint assessment of holiday travel. It is argued that more in-depth case studies focusing on different types of tourist activities are required to establish some representative examples for measuring the GHG emissions from holidaymaking in popular tourist destinations.

A small sample size of tourists utilised in this study is due to the primary focus of this thesis on demonstrating *how* to make accurate and holistic appraisals of carbon impacts from a holiday package rather than on measuring these impacts with the highest degree of precision. The analysis of the tourist sample in the Algarve has provided a good insight into the diversity and range of tourist activities available in this popular tourist destination. However, limited sample size hinders statistical generalization of this study results for all tourists in the Algarve. Hence, a comprehensive carbon footprint assessment of tourist activities undertaken by a bigger tourist sample would be beneficial for building an averaged and more representative tourist profile.

The scope of the hybrid DEFRA-LCEA approach can be extended and more empirical evidence of its employment can be obtained by applying it to other popular composite tourism products, such as city breaks and cruise tours. Utilisation of the new method for comparative carbon impact appraisal of the mainstream and eco-tourism products would be particularly interesting due to the on-going discussion in this field and the new, valuable insights which can be made by estimates of the 'indirect' GHG emissions.

Applying the DEFRA-LCEA technique to more holiday packages with selected parameters (for instance, provided by the same operator, offered in the same destination) can help identify the most and the least carbon-intense tours. This in turn may serve a basis for developing an ecolabel which would certify more sustainable holiday packages, given that many ecolabels are based on the lifecycle considerations. Budeanu (2007) argues, for example, that setting up an ecolabel for composite tourism products, such as holiday packages, can be beneficial in terms of creating a positive effect on tourist attitudes.

As this research has not addressed the 'indirect' lifecycle GHG emissions from hotel building, furniture and equipment due to the absence of data, it is recommended to conduct a separate case study on new hotel development to empirically understand the significance of the carbon contribution made to the total carbon footprint by the hotel building's (including furniture and equipment) construction, maintenance and disposal. This will provide empirical evidence to the literature estimates which claim that the contribution of the embodied GHG emissions from the hotel building to its total carbon footprint equates to about 15%. The issue of the carbon intensity of hotel refurbishments is of special concern as the refurbishment periods are short for hotels and may involve significant amounts of embodied energy. More research on the role that waste generation plays in the total carbon impacts from tourist accommodation and holiday package as a whole is also recommended.

9.6 FINAL CONCLUSIONS

This research has proposed a conceptual framework and an LCA modeling approach to assess the GHG emissions at a strategic planning and business level of tourism's products and services hierarchy, a holiday package tour. The feasibility of applying the proposed modeling technique in the tourism context has been demonstrated and its contribution to better understanding of the ‘indirect’ GHG emissions has been critically evaluated. The outcome of LCA has been compared against the results from the established methodological alternatives for measuring the carbon footprint from tourism products, services and activities to find the most rational tool, or combination of tools, for future tourism carbon footprint analysis. The new, hybrid DEFRA-LCEA (Ecoinvent) method has been proposed as a technique capable of making the most accurate and holistic estimates of GHG emissions from tourism products and services. The new method has been used to assess the impact of energy use scenarios associated with different options of holiday travel. The analysis has demonstrated that the proposed method can be employed to holistically evaluate energy and carbon saving potential of different tourism activities, serves a sound decision support tool for making more responsible holiday choices and may facilitate design of ‘greener’ tourism products and services.

Last but not least, this research set out to critically evaluate the potential for future LCA applicability in tourism. The results of the literature review and LCA-based case studies undertaken for different tourism products and services have revealed that the LCA method can be time and resource-consuming. This may imply that the tourism industry can be reluctant to broadly adopt this approach for appraisal of its environmental impacts. The issues with data requirements and costs of the life cycle inventories can hamper the successful employment of LCA by tourism businesses. At the same time, it is argued that if a sufficient number of indicative and robust LCA-based studies are undertaken for the most popular tourism products and services, this will provide a solid knowledge base on environmental impacts from which the industry, tourism and environmental authorities, academia and public can draw reliable conclusions about the actual environmental performance of tourism.

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GLOSSARY OF SELECTED TERMS

Term	Definition	Source
Capital goods	Goods, such as machinery, equipment and buildings, used in the life cycle of products or services	BSI (2008a)
Carbon dioxide (CO_2)	A naturally occurring gas and a by-product of fossil fuel combustion; one of the principal greenhouse gases (GHG) in the Earth's atmosphere	IPCC (2007)
Carbon footprint	The amount of GHG emissions generated 'directly' or 'indirectly' by a particular person, organization, activity, product or service and a way for individuals or organizations to assess their contribution to global GHG emissions	BSI (2008b); Johnson (2008)
Carbon impact	The adverse effects of greenhouse gas release on natural and human systems	IPCC (2007)
Carbon intensity	The amount of emission of greenhouse gases (GHG) per unit of, for example, product or service	IPCC (2007)
Climate change	A change in the state of the global climate that can be identified by the variability in its properties, and that persists for a long time period	IPCC (2007)
CO_2-eq.	Carbon dioxide equivalents are used to estimate the cumulative impact of all GHG gases, thus serving a single unit of measurement. *For example, the impact of a tonne of CH_4 is estimated as equal to 21 times the atmospheric impact of one tonne of CO_2; hence it is expressed as 21 CO_2-eq.*	Kelly and Williams (2007)
Direct carbon impacts	Energy consumption and related carbon footprint arisen while a product or service are in use	Bin and Dowlatabadi (2005)
Global Warming Potential (GWP)	The relative measure of the quantity of heat that a unit of a given greenhouse gas traps in the atmosphere, integrated over a chosen time period, commonly 20, 100 or 100 years, relative to that of carbon dioxide (CO_2). '100 years' is the most widely used time frame	IPCC (2007)
Greenhouse Gas (GHG)	A gas in the atmosphere, both natural and anthropogenic, that absorbs and emits thermal	IPCC (2007)

	radiation leading to occurrence of the greenhouse effect. The primary greenhouse gases are water vapour, CO_2, CH_4, N_2O and O_3	
Guest-night	One let bed per day (24 hours)	Nordic Ecolabelling (2008)
Holiday package	A pre-arranged combination of at least two of the following: transport, accommodation, and other significant tourist services which is sold at an inclusive price and has to cover a period of more than 24 hours or include overnight accommodation	Tepelus (2005)
'Indirect' ('embodied') carbon impacts	Energy consumption and related carbon footprint arising from the preparation (production and delivery) of a product or service, before, during (maintenance) and after (disposal) its use. *For example: driving a car leads to direct carbon impacts as petrol is used and GHG emissions are produced while a car is in operation. However, for this to happen, there are the 'indirect' carbon impacts related to the manufacturing of a car, its maintenance and disposal, provision and maintenance of road infrastructure, production and delivery of petrol, etc.*	Bin and Dowlatabadi (2005)
Life cycle of a product or service	All stages of a product or service life frame, starting with extraction of raw materials necessary to manufacture a product or service (cradle) and ending with its final disposal (grave)	Bin and Dowlatabadi (2005); Frischknecht *et al.* (2007a)
'Net' carbon impact *(from holiday travel)*	The difference between the carbon footprint produced by a tourist at the holiday destination and the carbon footprint which has been eliminated by not having stayed in the home country	Chenoweth (2009)
Primary energy	Delivered energy <u>including</u> production, efficiency, distribution and delivery losses	Yohanis and Norton (2002)
Radiative forcing (RF)	The change in the balance between radiation coming into the atmosphere and radiation going out, the so-called radiative forcing effect, due to the changes in concentration of greenhouse gases (GHG) at the tropopause, expressed in Watts per	IPCC (2007)

	square meter (W/m^2)	
Supply chain	Networks of processes that procure raw materials, transform them into intermediate goods and then final products/services, and deliver the products/services to customers through distribution systems. Supply chain of a final product can be described if all the interrelated processes required to produce it along with all input and output flows of intermediate goods are identified, wherever they are located	Albino *et al.* (2002)
Truncation error *(in the context of environmental assessment)*	Deliberate or unintentional omission of a portion of the total environmental impacts from a product or service due to the inability to account for all environmental contributions from the higher order suppliers	Lenzen (2000); Lenzen and Dey (2000)

LIST OF APPENDICES

Content of the Appendices

APPENDIX 1. FURTHER ANALYSIS

Carbon emissions calculators for leisure travel: what lies behind carbon footprint calculations?

Introduction:

A number of studies have explored online carbon calculators since better understanding and quantification of the corporate and individual carbon footprints is globally recognized as an important issue. Special attention has been given to the tools capable of measuring GHG emissions from flying as air travel is a significant contributor to the human-induced climatic changes. The primary focus of research has been on carbon offsetting. This is because most carbon calculators are designed as providers of monetary compensation for GHG emissions from businesses and individuals. For example, the study within the framework of the Tufts Climate Initiative conducted a criteria-based evaluation and ranking of 14 carbon calculators developed by the offset companies (Kollmuss et al. 2007). The evaluation criteria included the ease of use, comprehensiveness of carbon measurements, carbon offset price and quality of the offset projects. Ethical Consumer (2007b) conducted a comparative analysis of 13 carbon calculators with regard to offsetting costs. Gössling et al. (2007) discussed the implications of carbon offsetting throughout the assessment of efficiency and credibility of 35 carbon calculators. Likewise, Ethical Consumer (2007a) tackled the issues of transparency and credibility of selected offset providers. The profiles of the major carbon offsetting companies have also been reviewed (Kollmuss et al. 2006). Last but not least, the awareness and attitudes of air travellers to carbon offsetting have been investigated (Gössling et al. 2009).

Surprisingly, no research has addressed the question of what GHG emissions factors are employed by carbon calculators to quantify the carbon footprint of tourism-related activities. While it is clear that calculators are based on certain GHG emissions databases and carbon inventories, no structured knowledge on what data sources are employed in online carbon calculators exists. Moreover, no evaluation of the calculators from the standpoint of access and availability of the supporting background information to the public has been conducted. This issue is nevertheless important as carbon calculator users have a right to know how the GHG emissions estimates are made and how up-to-date and reliable the provided figures are.

This analysis therefore examines how carbon calculators measure GHG emissions from tourism and travel-related activities. It identifies the major GHG emissions inventories which lie behind the estimates. The primary focus of the review is on air travel as flying is addressed by the majority of the existing carbon calculators. The capability of the selected tools to measure the carbon footprint of tourism accommodation and leisure activities is also assessed.

The preliminary research revealed that the Internet abounds in carbon calculators but only a limited fraction deal with carbon emissions from tourism accommodation and leisure activities. The transport component was found to be well covered, with air travel being addressed by the majority of carbon calculators. It was however noted that different tools would provide different estimates of GHG emissions from flying, if the same travel itinerary was applied. This creates confusion and raises questions about reliability of the calculation results. Moreover, no background information had been found on some calculator's websites when an attempt was made to get familiar with the underlying calculation methodologies. Therefore, this analysis aims to better understand what methodological approaches, GHG emission factors and calculation assumptions are employed by the existing carbon calculators to measure the carbon footprint of air travel and other tourism components. The analysis also strives to understand to what extent the application of different underlying methodologies influences the calculations of GHG emissions. The relationships between the calculation methods are identified to understand their accuracy.

Methodology:

Carbon calculators were accessed via Google using the search phrases 'carbon calculator tourism' and 'carbon calculator travel'. Only those tools capable of estimating the carbon footprint of tourism and/or travel-related activities were analysed. This includes tools developed by offset providers. The primary focus was on air travel as the carbon footprint of flying can be assessed by many calculators. Within the air travel carbon calculators, only those tools focusing on international flights were reviewed. There are a number of calculators designed to estimate GHG emissions of national and/or domestic flights only (for example, Annual Carbon Emissions – ACE calculator from New Zealand). Such tools were not considered. Special attention was paid to carbon calculators capable of addressing tourism accommodation and leisure activities. This is because the GHG emissions from these tourism components can be difficult to quantify; hence, a limited number of estimates can be found in the literature. It is argued that it is interesting to identify what figures are employed by carbon calculators, especially by carbon offset providers, to check the origin of the background data and compare the calculation results against the values found in the literature. The tools limited to measuring the carbon footprint of other means of transportation (for example, the National Express Coach carbon calculator) and/or carbon emissions from households only (for instance, the Ebico household energy measurement tool) were not considered. Likewise, carbon calculators developed by airlines (for example, the EasyJet carbon calculator) were excluded as these tools measure GHG emissions of specific flights and thus lack flexibility in selection of tourist destinations. In addition, some airlines cooperate with carbon calculators and use their tools (for instance, the Climate Care calculator is utilized by Thomson Airways and First Choice Airways). Some carbon calculators are employed by travel-related companies and organizations (for example, the Bournemouth Airport uses the Carbon Clear calculator). Only original GHG emissions calculation tools were reviewed in this study. Finally, some online calculators are not available for free (for instance, the Air Routing International carbon emissions calculator). Such tools were not investigated in this review although the comparative analysis of the accuracy of the free-access and pay-for-access carbon assessment tools is considered for future research.

In total, 50 online carbon calculators have been analyzed (Table 1). This list is not comprehensive but it is argued to be representative enough to provide an insight into what background methodologies, GHG emissions databases and underlying assumptions are employed by the majority of carbon calculators in order to produce the estimates of GHG emissions for specific tourism activities.

The first stage of this review involved the analysis of the websites of carbon calculators. The quality of the available supporting information on how the GHG emissions calculations are made was evaluated. If the background data were not available and/or were unclear, the tool developers were contacted via email to seek clarification. The second stage of research consisted of the analysis of the background data obtained via the internet search and through email communication.

Findings:

1. **Tourism-specific vs. general carbon calculators:**

The review has shown that the number of online carbon calculators targeting emissions from air travel is significant but only a small portion focuses specifically on tourism. The tools whose primary focus has been found to be on ‘tourism activities’ (as claimed in the calculators’ description of targeted activities) are represented by 10 calculators (20% of the total number) while the remaining 40 tools (80% of the total) can be categorized as ‘other carbon calculators and offset providers’ capable of measuring GHG emissions of air travel but not focusing on tourism (Table 1).

Table 1. Carbon calculators under review.

№	Calculator name	Web address	Type of developer, country CC = Commercial Company NPO = Non-profit Organization)	Geographical scope of calculations
		Tourism-specific calculators		
1	CarboNZero	http://www.carbonzero.co.nz/EmissionsCalc/tourismeditor.aspx	CC, New Zealand	New Zealand
2	EcoPassenger	http://www.ecopassenger.org/	CC, Germany	EU
3	ETHOS	http://www.ethosbc.com/resources/travel-offset-calculator-0	NPO, Canada	International
4	NH Hoteles	http://www.carbon-clear.com/apps/nh/eicalculator.php?lang=en_ES&idc=1	CC, UK	International
5	Reduce my Footprint	http://www.reducemyfootprint.travel/individuals/calculators/airtravel.cfm	Joint project of ABTA - and AITO (Association of Independent Tour Operators), UK	International
6	ST CRC - Sustainable Tourism Cooperative Research Centre's holiday calculator	http://www.crctourism.com.au/Page/Tools+and+Products/Carbon+Calculator.aspx	Australian Commonwealth Government, Australia	Australia
7	Sustainable Travel International (STI)	https://sustainabletravelinternational.org/documents/op_carboncalcs.html	NPO, international	North America, Europe
8	Transport Direct	http://www.transportdirect.info/Web2/JourneyPlanning/JourneyEmissionsCompare.aspx	Joint initiative of travel operators and governmental bodies, UK	UK
9	Travelfootprint.org	http://www.travelfootprint.org/journey_emissions/?mode=plane	Joint project of the London Authorities and DEFRA, UK	UK
10	Carbon Balanced	http://www.carbonbalanced.org/personal/calculator/calctravel.asp	CC, UK	UK
		Other carbon calculators and offset providers		
11	Act on CO_2	http://actonco2.direct.gov.uk/actonco2/home.html	Joint cross-government initiative of DECC, Department of Transport and DEFRA, UK	UK
12	Action Carbone	http://www.actioncarbone.org/en/index.php	NPO, France	France, Europe
13	Atmosfair	https://www.atmosfair.de/en/emissions calculator/rechner/	Joint initiative of the German government, industry and NGOs	International
14	Bonneville Environmental Foundation	http://www.b-e-f.org/carbon/calc/	NPO, USA	USA
15	British Petroleum energy calculator	http://www.bp.com/iframe.do?categoryId=9032780&contentId=7060112	CC, USA	International
16	Carbon Advice Group	http://www.carbonadvicegroup.com/uk/index.php	CC, UK	UK

17	Carbon Clear	http://www.carbon-clear.com/calculators.php	CC, UK	International
18	Carbon Footprint	http://www.carbonfootprint.com/calculator.aspx	CC, UK	International
19	Carbon Fund	http://www.carbonfund.org/Calculators#Home	NPO, USA	USA
20	Carbon Neutral company	http://www.carbonneutral.com/carbon-calculators/	CC, international	International
21	Carbon Responsible	http://www.sustainabilityintelligence.com/AirCalculator/	CC, UK	International
22	Choose Climate	http://www.chooseclimate.org/	Individual, Belgium	International
23	Cleaner Climate	http://www.cleanerclimate.com/travel-calculator/calculator.php	CC, UK	International
24	Clear Offset	http://www.clear-offset.com/carbon-footprint-calculator-commute.php	CC, UK	International
25	Clear Sky	http://www.clearskyclimatesolutions.com/calculator.html	CC, USA	North America
26	Climat Mundi	http://www.climatmundi.fr/lng_EN_srub_10-CO-sub-2-sub-calculators.html	CC, France	France
27	Climate Care	http://www.jpmorganclimatecare.com/	CC, UK	UK, USA,
28	Climate Friendly	https://climatefriendly.com/flight	CC, Australia	International
29	Climate Positive	http://www.climatepositive.org/measure/	NPO, Australia	Australia
30	Cool Action	http://www.coolaction.com/ghg_calculator.php	CC, Canada	North America
31	Cool Climate (World Wild Fund carbon calculator)	http://coolclimate.berkeley.edu/	University of California, USA	USA
32	CO_2 balance	http://www.co2balance.uk.com/co2calculators/flight/	CC, international	UK
33	First Climate	http://www.firstclimate.com/popup/carbon-footprint-calculator.html	CC, Germany	Germany, EU
34	Food and Trees for Africa	http://www.trees.co.za/index.php?option=com_content&view=article&id=214&Itemid=73	NPO, South Africa	South Africa
35	Go Climate!	http://www.goclimate.de/kompensation/rechner/flug/	CC, Germany	Germany
36	Green Seat	http://www.greenseat.nl/CalculateCo2.aspx?calc=flight&lang=EN	CC, the Netherlands	The Netherlands
37	Grow Clean Air	http://www.treecanada.ca/site/?page=calculator&lang=en	NPO, Canada	Canada
38	MyClimate	https://www.myclimate.org/en/my/home.html	NPO, Switzerland	Switzerland
39	Native Energy	http://www.nativeenergy.com/pages/travel_calculator/465.php	CC, USA	USA
40	NETZERO	http://www.cleanairconservancy.org/calculator_air.php	NPO, USA	USA
41	Offsetters	http://www.offsetters.ca/node/445	CC, Canada	Canada
42	Offset the Rest	http://www.offsettherest.com/carbon-credits-calculator.html	CC, New Zealand	New Zealand, Australia, UK
43	Planetair (Canadian version of MyClimate)	http://planetair.ca/modules/smartoffset/offset.php?formid=air	NPO, Canada	Canada

44	Prima Klima	http://www.prima-klima-weltweit.de/englisch_2010/co2/kompens-berechnen.php	NPO, Germany	Germany
45	Pure	http://www.puretrust.org.uk/flights.jsp	NPO, UK	UK
46	Resurgence	http://www.resurgence.org/education/carbon-calculator.htm	NPO, UK	UK
47	Safe Climate	http://www.safeclimate.net/calculator/	Project of the World Resources Institute, international	International
48	Terra Pass	http://www.terrapass.com/carbon-footprint-calculator/#air	CC, USA	USA
49	United Nations Calculator	http://www.unemg.org/MeetingsDocuments/IssueManagementGroups/SustainabilityManagement/UnitedNationsGreenhouseGasCalculator/tabid/3975/language/en-US/Default.aspx	United Nations, International Civil Aviation Organization (ICAO), international	International
50	Zero GHG	http://www.zeroghg.com/carbon_calculators.html	CC, Canada	International

Furthermore, the capability of tourism-specific calculators to account for GHG emissions from all components of holiday travel, i.e. tourism transportation, tourism accommodation and tourism activities has been found to be limited. Only 2 tools (4% of total), namely CarboNZero and ST CRC calculator, give an 'all-in-one' option to measure the carbon intensity of holiday travel. 3 other calculators from the category of 'tourism-specific' (6%) offer an opportunity to quantify the carbon footprint of hotel stay but ignore tourism activities. The remaining 5 'tourism-specific' calculators focus on tourism transport component only.

Among 'other carbon calculators and offset providers' category, 7 tools give an option of measuring GHG emissions from hotel stay. This implies that, in total, only 12 carbon calculators (24%) deal with hotels. In addition to the small number of calculators capable of addressing the tourism accommodation component of leisure travel, a few other issues have been identified. Some tools are region-specific and the calculations they produce cannot be extrapolated globally. For example, Offsetters estimate GHG emissions from tourism accommodation in Vancouver, Canada, while NH Hoteles produce assessments in a small number of destinations and only for those hotels which belong to their hotel group. Carbon Balanced calculator is currently in the process of removing tourism accommodation from their tool as its primary focus in the future will be on offsetting of air travel only. This can be explained by the absence of demand and significant variations in existing estimates of the GHG emissions from hotels. ST CRC calculator has recently seized its operations; the calculations still can be made using this tool although no support is provided to the tool users. The NH Hoteles tourism accommodation calculator has lately been removed from the calculator's website. It is still available via the Google search but it is no longer supported by its developers. Both the ST CRC and NH Hoteles calculators have been contacted to clarify the origin of the background methodologies and to understand the reasons for seizing their operations. No response has however been obtained.

Tourism activities are addressed by even a smaller number of calculators. Only 5 tools (10%) have been found to offer an option of calculating GHG emissions from this component of holiday travel. Furthermore, only CarboNZero and ST CRC calculators, which belong to the category of 'tourism-specific calculators', give an opportunity to select from a broad range of tourism activities while the remaining 3 tools, classified as 'other calculators and offset providers', measure the fossil-fuel based (i.e. taking fuel consumption values as a basis for measurement) activities only. However, the CarboNZero and ST CRC calculators are New Zealand and Australia-specific; hence, the values they generate should be taken with caution if GHG emissions from tourism activities in other parts of the world are to be quantified. This implies that no carbon calculators are capable of producing solid and worldwide-applicable measurements of GHG emissions from leisure activities.

As for tourism transportation, this component of tourism is well addressed. In addition to air travel, the majority of calculators are capable of estimating the carbon footprint of different transportation options, although the preference is given to cars and/or surface transport. Only 4 tools (8%) have been found to concentrate exclusively on quantifying GHG emissions from flights and 10 (20%) calculators are capable of accounting for literally all means of transportation.

This preliminary analysis shows that tourists willing to measure the carbon footprints and offset GHG emissions from all components of their holiday travel, i.e. tourism transportation, tourism accommodation and tourism activities, are limited in opportunities. The calculations can be made separately, i.e. by using several different calculators. No single calculator exists which would target all tourism components at once and whose calculations could be extrapolated globally. This can be partially explained by the lack of reliable calculation methodologies for quantification of GHG emissions from hotel stay and leisure activities. This results in the absence of reliable estimates which could be generalized and/or extrapolated to cover tourism components in different geographies. It is argued that more research is required in the area of quantifying the carbon footprint of hotel stay and leisure activities as the results obtained might be of use not only to specific tourism businesses, to better understand their carbon footprints, but also to carbon calculators and offset providers, to provide a wider range of offset opportunities and produce science-supported estimates.

2. Geography of carbon calculators and the nature of their developers:

Most carbon calculators are based in UK (15 or 30%), USA (8 or 16%) and Canada (6 or 12%). 5 (10%) calculators are represented globally, i.e. they either have offices in more than one country and/or are administered by the international organizations. Germany hosts 5 (10%) calculators, Australia – 3 (6%), New Zealand – 2 (4%), France – 2 (4%). Switzerland, South Africa, Belgium and the Netherlands run 1 carbon calculator each. As for the geographical applicability of calculations, it is fair to suggest that all tools have global coverage as air travel is an international activity. However, if air travel is excluded, the primary geographical focus of carbon calculators varies. Most tools are capable of producing GHG emissions estimates globally - 16 calculators (32%); 11 (22%) focus on USA and Canada and 8 calculators (16%) are UK-specific.

Most calculators are developed by commercial companies (26 or 52%) followed by non-profit organizations (14 or 28%). 3 calculators (6%) are administered by the public authorities, 2 (4%) – by the consortium of the public authorities, industry representatives and non-governmental organizations (NGOs), 2 (4%) – by the industry and tour operators associations. University, individuals and the World Resources Institute (WRI) have also developed their own calculators (3 or 6% in total).

3. Quality of presentation of the background methodologies:

The review has revealed that carbon calculators provide limited information on the methodologies employed for GHG emissions estimates, emissions conversion factors utilized and the assumptions applied to calculations of air travel. However, contrary to the evidence from the literature (Chenoweth 2009) and initial expectations, many tools do provide good details of the background data used. Some calculators (for example, Offset the Rest and NetZero) present in-depth methodological explanations and even supply examples of calculations. However, such practices have been found to be an exception, rather than a general rule.

In total, 20 calculators (40% of the total) were sent inquiries to seek clarification as the information available on their websites did not contain any supporting data and/or if the supporting information was unclear. For instance, the Reduce my Footprint calculator explains the basis for their calculations as

'..*emissions are calculated using published information on energy consumption. The data that we use are best estimates available, within the limits of practicality, using government sources wherever possible*'.

This is an example of a typical explanation to how the GHG estimates are made as found on the calculator's website and this is the situation when an inquiry has been sent to the tool developer asking for more detail.

Some calculators tend to explain in simple terms where the background information comes from. Such a strategy is well understood as the calculator users may not be looking for too much detail and/or they may have no appropriate scientific background to understand how the calculations are made and what they are grounded on. However, the explanations provided are often too simplistic and the references to the data sources are very qualitative. Generic words are commonly used like, for example, 'best estimates', 'reliable governmental sources' or 'internationally recognized emissions factors'. Some tools mix up the calculation approach with the background source of information and/or methodologies. For example, the Offsetters calculator refers to the work by Jardine (2008) as a source of data for calculations. However, email communication has revealed that, in reality, it relies on GHG conversion factors from DEFRA – Department for Environment, Food and Rural Affairs (UK). Likewise, the Green Seat calculator provides a reference to IPCC – Intergovernmental Panel on Climate Change although it has been found that calculations are made on the basis of data from the GHG Protocol. In both cases, IPCC and Jardine (2008) propose an approach to account for GHG emissions from air travel at higher altitudes, while all background data are provided by other sources.

Many calculators 'hide' background information. It is often embedded in the Help section of the Business calculators as many offset providers measure GHG emissions from individual and corporate activities, thus offering two separate calculation tools. Business carbon emissions tool, rather than Individual carbon emissions calculator, contains all background information in the calculator developed, for instance, by the Carbon Neutral Company. This is probably self-explanatory as businesses are the primary clients of carbon offset providers. However, individuals should also be given an opportunity to get easy access to the background data; otherwise, the calculations' credibility will be questioned by the tool users.

If no response was obtained from the calculators within 2 weeks of making an email inquiry, a reminder had been sent. 10 calculators replied to inquiries supplying the necessary clarifications. This represents only half of the contacted tools. The remaining 10 calculators which do not provide any supporting methodological information online and which have not replied to inquiries have been assigned the value 'information not available'.

Interestingly, some calculators (for example, Cool Action, ETHOS and NH Hoteles) present their calculations as such, giving no (even simplistic and qualitative) guidelines and/or insights to how the figures have been obtained. No response was either provided when the inquiries had been sent. Moreover, unlike other calculators, these tools give no introduction to the problem of GHG emissions and carbon offsetting, i.e. the FAQ or Help section is not present on their websites. It is argued that such a practice is to be avoided, although the reason behind presentation of no background data can also be understood. The developers of these tools may probably assume that the calculator users should have already been familiar with the topic of carbon footprint and offsetting if they have visited the calculator's website. Even though such an assumption is justified, it is deemed that carbon calculators should provide at least basic explanations to the problem they are dealing with.

4. Basis for calculations:

The review has revealed that most calculators (17 or 34%) use the GHG conversion factors from DEFRA - Department for Environment, Food and Rural Affairs (UK) as a basis for calculations (Figure 2.1). The GHG emissions factors for air travel from DEFRA stem from the modelled fuel consumption information supplied by the aircraft-specific EMEP/CORINAIR emissions inventory guide (EEA 2009) which was first published by EEA - European Environment Agency in 2007. It is further combined with the data from the UK Civil Aviation Authority (DEFRA 2009). The EMEP/CORINAIR emissions inventory guide is in turn based on the aircraft performance model PIANO-X developed by the UK-based commercial software company Lissys (International Civil Aviation Organization - ICAO 2009). Although the GHG conversion factors from DEFRA are developed by the UK public authorities and can, therefore, be considered as UK-specific, a number of calculators from outside the UK rely on this method (for instance, CarboNZero from New Zealand or Offsetters from Canada).

The second most popular source of the GHG emissions factors employed by calculators (12 or 24%) is the Greenhouse Gas (GHG) Protocol initiative which has been developed by the WRI – World Resources Institute (WRI 2008). The review of its underlying methodology has however revealed that the GHG Protocol is, at least partially, based on the DEFRA GHG conversion coefficients. These are further supplemented with the data from IPCC (IPCC 2006) and United States Environment Protection Agency (US EPA) (WRI 2008). This implies that the GHG emissions factors from the GHG Protocol can be considered as a derivative from DEFRA, rather than as an independent method for calculation of carbon footprint of air travel. It has further been found that DEFRA is predominantly employed by the UK-based carbon calculators while the GHG Protocol is widely utilized by the US-based tools.

It has been discovered that not all calculators are aware about the relationship between DEFRA and the GHG Protocol. The Carbon Responsible calculator, for example, is the only tool that gives an opportunity to calculate GHG emissions by applying two alternative methods, i.e. the GHG Protocol and DEFRA. When the same flight is selected (London Gatwick – Faro has been used for this research, see 'Accuracy' section for more details), the difference in results turns out to be negligible, i.e. 0.36 (DEFRA) vs. 0.37 (GHG Protocol) tonnes of CO_2. It is argued that this finding may serve as another justification for why this research has been conducted as calculators should better understand the underlying methodologies behind their calculations and be aware about the differences between them.

It has been discovered that four calculators (8%) are based on national GHG emissions inventories. These are developed by the national public authorities who often employ the figures from the GHG Protocol but supplement them with some industry and/or nation-specific data. The France-based Action Carbone and Climat Mundi calculators utilize the GHG emissions coefficients from the Bilan Carbone GHG emissions accounting method developed by ADEME (French Environment and Energy Management Agency) (ADEME 2007); the Australia-based Climate Positive calculator – on the emissions factors from the Australian Department of Climate Change, while the Eco Passenger calculator from Germany employs the TREMOD (TRansport Emission MODel) GHG emissions calculation model developed by the Institute for Energy and Environmental Research (IFEU) for German Federal Environment Agency (IFEU - Institut für Energi und Umweltforschung 2008). There are no conceptual differences between these methodologies and the method from DEFRA. All these methodologies are based on the national statistics and/or data from the national industries, hence figures they provide are more representative for those countries where the methodologies have been developed. It is argued that, as regards air travel, DEFRA and/or the GHG Protocol should be a preferred tool due to their broad acceptance and international recognition. The regular updates of the GHG emissions coefficients from DEFRA and the GHG Protocol is another advantage of these methodologies.

Four (8%) calculators have been found as based not on a single source but on a collection of data sources. The analysis has revealed that some of these sources also utilize information from DEFRA and the GHG Protocol, supplemented with the data from a number of different government and industry-specific databases and inventories. The Atmosfair calculator, for instance, employs a combination of sources, including IPCC, German government, Lufthansa and expert estimates. Likewise, the My Climate calculator claims to be simultaneously using the data from DEFRA, EEA and IPCC. In the latter case, while it is accepted that such a combination of data sources is possible, it is argued that only a single source has been employed for calculations in reality, with other sources being supplementary and/or outlining the major approach only (see above for discussion).

One calculator (Bonneville Environmental Foundation) has been reported as using the data from the IPCC aviation fuel emissions database (IPCC 2006); the United Nations carbon calculator argues to employ the figures from the EMEP/CORINAIR emissions inventory guide, which is put in the basis of DEFRA GHG conversion factors, directly. The Canadian Grow Clean Air calculator claims to be grounded on data which cannot be fit into any of the identified sources, namely:

'..conversion factors were provided from VCR Inc Challenge Registry Guide to Entity & Facility Reporting – Unit Conversion Tables'

No response has been obtained when seeking clarification on this method, hence it is difficult to draw conclusions on whether or not this is an independent method for calculation of GHG emissions from air travel.

Finally, 10 calculators (20%) have provided no background information on their websites and sent no response to the clarifying inquiries, hence the primary source of data for calculations has not been identified.

5. Currency of calculations:

The review has identified that many calculators are out of date. First, the reference date for the GHG emissions databases and inventories which are used for calculations is not specified by over half of the tools. Only 24 (48%) calculators clearly state the reference year of the employed datasets on their websites. The remaining 26 calculators provide no information on how up-to-date the sources of information are. When contacted for clarification, only 3 tools have provided the reference date. In both cases it has turned out that the numbers are not up-to-date, which leads to another issue: many of those 26 calculators which have the reference date for their datasets published have appeared to be based on dated GHG emissions coefficients. Only 8 calculators (31% of those with a reference year provided) use the most up-to-date GHG conversion factors from 2009[1] while 10 tools (38%) employ coefficients produced in 2007 and earlier. The British Petroleum calculator is based, for example, on the GHG conversion factors developed in 2005, while Cool Climate – in 2003. The reasons for employing dated coefficients and irregular updating of calculators are many-fold and may be related to the lack of staff, absence of demand and other factors. It is argued however that the use of the dated figures on GHG emissions from air travel is in interest of carbon offset providers. This is because the fuel and, consequently, carbon efficiency of flights is gradually improving. This can be seen, for instance, by looking at the evolution of the 2007-2009 DEFRA GHG conversion factors for short-haul flights which suggest a lower figure with each consecutive year (given that only 'direct' emissions are considered). However, offset providers, especially commercial companies, should potentially be more interested in getting higher offsets. This can be achieved by applying older, and therefore more carbon-intense, GHG emissions factors which increase the values of the calculated carbon footprint and may thus increase the monetary gains. Therefore it is argued that it is crucial for carbon calculators, especially for those developed for carbon offsetting purposes, to keep the background GHG conversion factors up-to-date. This will help calculators avoid criticism and should enhance transparency and credibility of their calculations.

More important, it has been revealed that some calculators administered and run under the aegis of the governmental organizations (for example, the Act on CO_2 calculator which is an official tool of the UK environmental and transport public authorities and Safe Climate which has been developed by the World Resources Institute, i.e. the same institution that develops the GHG Protocol initiative) are either based on dated GHG emissions coefficients or provide no information on the reference year of estimates. The Act on CO_2 calculator uses the 2008 DEFRA GHG conversion factors while the Safe Climate tool gives no reference year at all. The latter case can possibly be explained since the Safe Climate calculator users are expected to be familiar with

[1] DEFRA have recently published the new, 2010 edition of GHG conversion factors. However, when this analysis was conducted, the 2009 GHG emissions coefficients were the most up-to-date figures.

the estimates produced by the GHG Protocol, hence no further clarification and/or guidelines are deemed to be necessary. However, since the calculator is run independently and can be found via the Google search, it is argued that detailed background information needs to be supplied to its users.

6. Accuracy:

The accuracy of the calculators' estimates has been evaluated to understand which tools produce the most accurate figures of GHG emissions from air travel if compared to the original calculation methodologies they are based upon. The analysis indicates that there is a significant discrepancy in GHG emissions estimates. The primary factors which influence the magnitude of the calculated values are as follows:

Some calculators account for the radiative forcing (RF) effect imposed by the GHG emissions released by aircraft at high altitudes. The science behind the RF effect is still uncertain and its magnitude is calculated with a range of 1.9-4.7 (Grassl and Brockhagen 2007). To account for the RF effect, IPCC (Penner et al. 1999) recommends a multiplier of 2.7 while DEFRA (DEFRA 2009) advises a multiplying factor of 1.9. There is however no agreement in the literature whether or not the RF multipliers should be included in the estimates of GHG emissions from flights. Foster et al. 2006) argue, for instance, that the application of the RF multipliers may lead to the overestimation of the aviation's GHG emissions; hence some carbon calculators do not follow the IPCC and DEFRA guidelines. The Act on CO_2 carbon calculator, which is an officially recommended GHG calculation tool from the UK environmental and transport public authorities, does not, for example, apply any RF multiplier.

Apart from the RF coefficient, some calculators employ additional multiplying factors in their estimates. The IPCC recommended 9% uplift factor accounting for indirect aircraft routing, circling and delays (DEFRA 2009) is, for instance, embedded into the estimates of all calculators based on the DEFRA GHG conversion factors. Since DEFRA GHG conversion factors lie in the basis of the GHG Protocol method, it is fair to assume that the GHG Protocol also applies the 9% uplift factor. Any multipliers used by the reviewed calculators as stated in the calculators' supporting documentation and/or obtained via direct communication with the calculators' developers are listed in the appropriate section of Table 2. The estimates of GHG emissions produced if no multiplying coefficients have been applied are also presented in this section.

The accuracy of the reviewed calculators has been checked against standard figures. Since DEFRA GHG conversion factors have been found to be the most popular source of background data for calculation of GHG emissions from air travel, the values from the most recent DEFRA report (DEFRA 2009) have been used for a comparative analysis. Note that the accuracy assessments of carbon calculators for flying have already been held (see, for example, Gössling et al. 2007; IFEU 2010); however, the existing studies provide no insight to the background methodologies in order to understand the reasons for discrepancies. The previous accuracy assessments are thus limited to the presentation of figures, with no in-depth analysis of the calculation results.

According to DEFRA, the return flight from London Gatwick to Faro generates **0.32 tonnes** of CO_2-eq. This figure has been obtained by multiplying the 2009 DEFRA GHG conversion factor for short-haul flights (according to DEFRA (2009), short-haul flights are less than 3700 km of length) by the distance travelled. When the 9% uplift factor is added, this number converts to 0.35 tonnes of CO_2-eq. If the carbon footprint of the flight is calculated by using the GHG Protocol GHG emissions coefficients, the figure of 0.345 is obtained. Assuming that this number integrates the 9% uplift multiplier, the 'original' GHG emissions (without any multiplying factors applied) equate to **0.317 tonnes** of CO_2-eq., i.e. it is almost identical to the DEFRA value.

Interestingly, it has been discovered that even 'twin' carbon calculators (for example, Planetair is a Canadian daughter version of the Switzerland-based My Climate tool) yield different results when estimating GHG emissions. While fair for car travel and household activities which rely on nation-specific carbon intensities of fuels, this is also the case for air travel which is international and whose estimates should not, theoretically, vary to a significant extent. In the case of Planetair and My Climate the discrepancy has however been found to be fairly significant, i.e. up to 20%. Planetair estimates the carbon footprint of London Gatwick – Faro return flight as equal to 0.6 tonnes of CO_2-eq. (0.27 if the RF multiplier of 2.0 and the 9% uplift factor are deducted), while My Climate suggests a higher value of 0.7 tonnes (0.32 if the RF multiplier of 2.0 and the 9% uplift factor are deducted). Although the Planetair is based on the GHG Protocol whereas My Climate employs the DEFRA GHG conversion factors, this should not lead to the 20% difference in the calculated values as both methods are essentially the same. This raises questions about the reliability of carbon calculators and calls for harmonization in their estimates.

7. Application of multipliers:

The review has identified that there is no consistency in the use of multipliers in carbon calculators. This finding is in line with the results of the earlier analysis conducted by Gössling et al. (2007) who show that the multiplying coefficients employed by calculators may vary to a significant extent. There are at least 3 types of multipliers applied in carbon calculators.

1. The radiative forcing (RF) effect multiplier.

The RF multiplier used in calculators varies from 1.0 to 3.0, with 1.9 being the most popular value (Table 2). The figure of 1.9 is recommended by IPCC and DEFRA but the decision on whether to include or to exclude it from calculations is left to the discretion of calculators. As Table 2 suggests, there is currently no agreement among calculators about the magnitude of this value applied.

Table 2. Application of the RF multipliers in carbon calculators.

RF multiplier	Number of calculators where it is used	% of total
1.0 (no multiplier)	5	10
1.9	10	20
2.0	8	16
2.5	2	4
2.7	8	16
3.0	4	8
Information not given	13	26
Total	50	100

A significant number of calculators (26% of total) do not provide any detail on whether or not they employ any multiplier. Among these, 4 calculators are believed to use the RF multiplying coefficient. This is because the calculated figures of GHG emissions and their comparative analysis against the numbers from other tools, produced by identical methods, suggest that the RF multiplier has been applied (for example, the Transport Direct calculator is possibly using the DEFRA recommended RF multiplier of 1.9). However, the precise values of a multiplying coefficient used are unclear as no background information is presented and no clarification has been obtained via email inquiries.

If compared to the analysis of carbon calculators performed by Gössling et al. (2007), it becomes evident that the RF multipliers are more widely used nowadays than three years ago. According to Gössling et al. (2007), almost half of the 35 calculators reviewed in their study used no RF multiplier, i.e. RF multiplier = 1.0, while only 14% of all tools employed the RF multiplier > 2.0. This is in contrast to the findings of the current study where the figures are 10% and 28%, respectively. Since the science about the RF effect is still uncertain, it is argued that the popularity of the RF multipliers nowadays can be, at least partially, explained by the willingness of carbon calculators to earn higher profits. Higher RF coefficients applied in calculations of GHG emissions from air travel generate higher monetary gains for carbon offset providers. It is therefore argued that, to avoid criticism, carbon calculators should provide an option to include/exclude the RF multiplier in their carbon footprint estimates. Only 4 calculators (EcoPassenger, Carbon Fund, Clear Offset and Planetair), giving such a degree of flexibility to their customers, have been identified.

2. The 9% uplift multiplying factor.

The uplift multiplier is recommended by IPCC and DEFRA. It is included into calculations of GHG emissions based on the DEFRA GHG conversion factors. Since the GHG Protocol estimates are based on values from DEFRA, all calculators relying on this background methodology have also got the 9% multiplier included. It is however unclear whether or not this factor is taken into account by the calculators grounded on alternative GHG emissions calculation methodologies as no explanations are provided.

3. Multipliers aiming to account for 'indirect' GHG emissions concomitant with fuel production, delivery and distribution.

Only 5 calculators (Action Carbone, Cool Climate, EcoPassenger, First Climate and Travelfootprint.org) include this multiplier in their estimates of the carbon footprint of flights. It aims to account for additional GHG emissions embodied in the aviation fuel production and distribution chain (see Frischknecht et al. (2007) for an overview of the 'indirect' carbon footprint). Cool Climate is the only calculator that specifies the magnitude of this factor, namely 1.2. Other tools mention this multiplayer but provide no specific values. The evidence from the literature shows that the contribution of these 'hidden' emissions to the total carbon footprint of tourism transportation can be significant (Frischknecht et al. 2007); hence, it is argued that carbon calculators should consider the inclusion of these GHG emissions into future calculations. Moreover, there is evidence that the 'indirect' GHG emissions concomitant with vehicle manufacture and transportation infrastructure (for example, roads, railways, airports) are also significant (Frischknecht et al. 2007). At the moment, Climat Mundi is the only tool that accounts for these additional ‘indirect’ emissions; however, the multiplier applies only to cars and motorcycles while no multiplying coefficient is used for air travel. It is argued that the corresponding multipliers, aiming to account for this ‘hidden’ carbon footprint, should also be included in carbon calculators, at least as a voluntary ‘opt-out’ option.

8. Unit of measurement:

The analysis has shown that there is no consistency among calculators when it comes to the unit for measurement of GHG emissions from air travel. 25 calculators (50%) measure carbon footprint in ‘kg of CO_2’, while 23 tools (46%) use the unit ‘kg of CO_2-eq’. The difference between these units is in the magnitude of GHG emissions accounted for in estimates. If the whole range of GHGs is taken into account, then the unit of measurement should be ‘kg of CO_2-eq’ as it reflects the higher global warming effect of non-CO_2 GHGs. The RF multiplier converts the climatic impacts of non-CO_2 gases to those of CO_2 (IFEU 2010). This implies that all calculators utilizing the RF multiplying coefficient should be based on the unit ‘kg of CO_2-eq’. However, it appears that some calculators do not understand this difference and measure carbon footprint in ‘kg of CO_2’ even if the RF factor has been applied (see, for example, Atmosfair, Cleaner Climate).

It is important to note that some calculators make no difference between these units and use them interchangeably, as has been discovered in email communication, although the figures of GHG emissions expressed in ‘kg of CO_2-eq’ should be higher. More important, the DEFRA GHG conversion factors 2009 recommend but do not apply the RF multiplier. They however measure the climate change impacts of CH_4 and N_2O; hence, the unit of measurement is referred to as ‘kg of CO_2-eq’.

Some calculators use the units of measurement misleadingly. The Offset the Rest calculator, for example, makes calculations on the basis of the DEFRA GHG conversion factors developed in 2007. The unit of measurement as referred to on the calculator’s website is ‘kg of CO_2-eq’. However, the DEFRA GHG conversion factors 2007 provide the estimates in ‘kg of CO_2’ emissions; hence, ‘kg of CO_2’ should have been the unit for measurement in the calculator, not ‘kg of CO_2-eq’.

1 calculator (Travelfootprint.org) argues that it quantifies GHG emissions in ‘kg of lifecycle CO_2’ where ‘lifecycle’ implies that the ‘indirect’ emissions from fuel production

and distribution chain are taken into account. The Food and Trees for Africa calculator uses the units ‘kg of CO_2’ and ‘kg of carbon’.

9. Calculation of distances flown: short-haul vs. long-haul air travel:

It has been revealed that no agreement exists among carbon calculators as regards the definition of a short-haul distance for air travel. The First Climate calculator defines short-haul flights as those of up to 450 km (one-way) in length. This definition is provided by WRI and it is close to the one broadly accepted in North America, i.e. 500 km, although some North American calculators like, for instance, Offsetters, British Petroleum and Clear Sky, suggest the distance of 560 miles (900 km) for short-haul air travel. In contrast, short-haul flights in Europe are generally based on longer distances. Peeters and Schouten (2006) suggest the length of 2000 km, the Small World Consulting carbon calculator (not covered in this review) argue for 2500 km, while DEFRA provides the largest value of 3700 km (DEFRA 2009). It has been discovered that some calculators (for example, Clear Sky) use different definitions of short-haul flights in Individual and Business calculators. In the Clear Sky case, the Individual carbon calculator categorizes short-haul flights as those of up to 560 miles (900 km) in length, while the Business calculator suggests the distance of up to 300 miles (480 km). Simultaneously, Clear Sky gives an option to calculate GHG emissions per number of short-haul flights; this may result in significant discrepancies in calculations made by the Individual and Business calculators as different definitions of the short-haul distance flown are applied.

The significant variance in estimates of short-haul distances for air travel causes confusion and may even lead to calculation mistakes. This is because some calculators apply different RF multipliers to the flights of a different length. Offsetters and First Climate, for instance, employ the RF multiplying coefficient only to medium and long-haul air travel. Short-haul flights (up to 500 km for Offsetters and up to 450 km for First Climate) are not multiplied because it is claimed that they do not reach higher altitudes and, as a result, they should not produce GHG emissions which may cause the RF effect. This statement may indeed be applicable to short-distance flights; however, if the DEFRA definition of short-haul air travel is taken, then this implies that no RF multiplier should be employed when calculating GHG emissions from flights up to the distance of 3700 km. The flights of 3700 km in length do cause the RF effect; hence, this leads to confusion.

The distance-dependant use of a RF multiplier has not found reflection in some other calculators. The Bonneville Environmental Foundation tool applies the RF factor of 2 and Cool Climate – the RF of 1.9 in all circumstances. The Resurgence calculator applies RF = 2 to domestic flights and RF = 3 – to international flights. Given that this tool is UK-specific, some domestic flights (for instance, London – Manchester, 265 km) are short-haul which implies that the Resurgence calculator will generate 2-times higher estimates of GHG emissions compared to Offsetters and First Climate which do not employ a multiplier for short-haul travel ranges.

More important, the review has identified that different approaches are applied to the calculation of flight distances. Some calculators make their estimates on the basis of flight duration (i.e. in hours like, for instance, Food and Trees for Africa and Zero GHG) which are then automatically converted in length. The conversion method is not reported although it is assumed that the average cruising speed of a modern aircraft multiplied by the time flown is used. To give an example: the First Climate calculator defines the average cruising speed as 1 hour = approx. 800 km. It is however argued that this method is not precise as some short-haul flights do not reach cruising altitudes. The British Petroleum calculator quantifies GHG emissions of particular flying distances, not specific flights. Only the flights of 500 km in length (defined as short-haul) and 5000 km (defined as long-haul) are offered for analysis. If the short-haul flight is longer than 500 km, then a certain numbers of flights need to be selected for making calculations. For instance, for a flight of 1500 km in length, 3 short-haul flights are to be analyzed. No calculation option is given if the flying distance cannot be made of 500 km chunks (like, for example, 1210 km). Similar approach is employed by the First Climate calculator where the chunks of 500 km are used for calculations. This limits the precision of estimates. Finally, the Resurgence calculator measures GHG emissions on the basis of hours flown, equating 1 hour to 400 km distance. It is however unclear what lies behind this conversion as the average cruising speed of a typical aircraft is significantly higher.

Some carbon calculators have been found to be even cruder. The Verus Carbon Neutral calculator (not included in this review) defines long-haul flights as those of '3-6 hours' in length while Clear Sky (see above) defines 'long-haul' flights as those up to '8-12 hours' in duration. It is however unclear what precise distance is taken for calculations from these ranges (assuming that the distance is measured on the basis of the average cruising speed of an aircraft, see above) as no explanations are provided. Last but not least, some calculators estimate GHG emissions from air travel by counting the number of flights per year (Small World Consulting, not covered in this review). No explanation is however provided to the length and/or duration of the flights to better understand the calculation approach.

10. Other issues:

A few other, less significant, issues have been identified:
Calculators employ different assumptions as regards the aircraft occupancy. Most tools are based on the average occupancy rates of 65-80%, while some calculators produce estimates on a 'per seat' basis, i.e. the occupancy is assumed to equate 100% (for example, Climate Care, Climate Friendly).

Some calculators are limited in the number of flying distances and destinations available for estimates. Either only specific airport can be selected or only approximate distances between cities and/or regions can be applied (for example, London – Algarve, Climat Mundi).

Carbon calculators use different measurement units for distance and weight. Miles and pounds are popular with North American and British tools; no option is provided to switch between metric and imperial systems. It is deemed to be not a problem as long as the GHG emissions estimates are precise; however, this questions the convenience of use and global accessibility of the calculators. While the residents in the UK and North America are familiar with the imperial system, the residents in continental Europe may not be.

As a result of the growing market of carbon offsetting the names of some carbon calculators are similar and this may easily cause confusion. Moreover, some carbon offset providers use calculators developed by other entities. For example, the calculation tool offered by Carbon Balance Consulting (Australia, not covered in this review) uses the calculator developed by Carbon Footprint (UK) with no proper reference provided. This may question the quality of calculations made by these 'secondary' calculators as the original tools may utilize nation-specific emission factors which would not be applicable to other regions without additional adjustments and adaptation to the local conditions.

Last but not least, not all carbon calculators are available in English. The Go Climate! Tool is only run in German; no international version of the website exists.

11. Tourism-specific carbon calculators and issues related to them:

The analysis of carbon calculators has revealed that only a limited number of tourism-specific calculators are available online. However, and contrary to the initial expectations, there are a few tools which can be used to measure GHG emissions of all components of holiday travel, i.e. tourism transport, accommodation and activities, at once. Furthermore, a number of good-quality tools capable of assessing the carbon impacts of the whole spectrum of tourism products can be found among those developed by carbon offset providers (for instance, Cleaner Climate, Carbon Neutral Company). Concurrently, some calculators of a mediocre quality have been identified among those tools whose primary focus is claimed to be on tourism (for example, Reduce my Footprint, Travelfootprint.org) as they fail to account for carbon footprint arising from some fundamental components of leisure travel (namely, tourism accommodation and activities are not addressed). Surprisingly, some calculators developed and run under support of the national governments have tourist activities entirely ignored. The official carbon calculator of the US Environmental Protection Agency (EPA) for US households (not covered in this review), for example, does not produce the estimates of GHG emissions for leisure activities and air travel. It is claimed that air travel is not addressed due to the significant variations in the estimates of its carbon footprint (US EPA – United States Environmental Protection Agency 2010). Explanations to why leisure activities and tourism accommodation are excluded are not given. It is argued that such an approach is incorrect and that at least air travel should always be included in carbon calculators, at least in the form of the best estimates, with acknowledgment of the major issues related to calculations. The interested public should be aware of the entire range of their carbon footprints despite the complexities existing in measurements of carbon intensities of certain activities.

It is fair to suggest that all the issues identified in the general review of carbon calculators are relevant to tourism-specific calculators. There are a few more points which need to be highlighted in this category of tools:

Most calculators offer a broad variety of available geographies for calculation of carbon footprint of flights. However, some tools (for example, the EcoPassenger, Reduce my Footprint and ST CRC calculators) are limited to certain destinations. The limitations are sometimes so significant that a number of popular flights (destinations) are not addressed. The EcoPassenger calculator, for instance, cannot produce calculations of GHG emissions from the itineraries of London – Lisbon or Stockholm – Madrid although they are believed to be fairly popular with tourists. Surprisingly, but many carbon offset calculators offer more tourist destination options.

Contrary to the GHG emissions factors for air travel, it has proven to be problematic to figure out what GHG conversion factors lie behind the calculations of the carbon footprint of tourism accommodation and activities. The significant variance in estimates exists when calculations are made by applying different calculators. This causes confusion and raises questions about the reliability of results. In most cases the background data are absent and no references are available on the websites. The attempts to seek clarification have also failed; hence it is difficult to understand how the values are produced. The ST CRC calculator, for example, offers an opportunity to measure the carbon footprint of a broad range of tourism accommodation facilities and tourism activities in Australia. However, the quality of these estimates is limited as no explanations are provided on how the figures are produced and no reply has been received when clarifications were sought.

A few more methodological issues with measuring the carbon footprint of holiday activities have been identified:

The carbon footprint of tourism accommodation is often calculated as part of the GHG emissions balance of an event, rather than holiday travel (see, for example, Climat Mundi). In other words, the Individual carbon calculators do not measure the carbon intensity of hotels, although the Business tools do (see, for instance, Clear Sky and MyClimate). It is argued that such an approach should be avoided and that the option to calculate the carbon footprint of tourism accommodation should also be included into the Individual carbon calculators.

Some calculators capable of estimating the carbon footprint of tourism accommodation have been found to be based on dated background information. The STI calculator, for example, employs the GHG emissions factors from 1990s for the North American hotels, while the 2004 emission factors are used for the European tourism accommodation facilities. The dated background information for North America may partially explain the reason for why the calculated carbon footprint of hotels in Europe is circa 3.5 times lower than the carbon footprint of hotels in North America; although the general higher carbon intensity of the North American hotels should also be acknowledged.

It has been found that the same datasets may serve as a basis for calculations in some tools. Carbon Fund and Clear Sky, for example, use the numbers from the US EPA. Interestingly, but no direct reference to the source is provided and, when contacting for clarification, it has turned out that the figures were obtained indirectly, as the EPA report, that both calculators are referring to (see Energy and Environmental Analysis 2005), does not provide any numbers on GHG emissions. Instead, it contains an inventory of energy consumption in >1000 US hotels. The necessary calculations of the carbon footprint were made by the calculator developers themselves, using the available GHG conversion factors from US EPA. Although it is deemed that these numbers are fairly reliable, no external verification of the estimates has been conducted.

Some calculators make estimates on the basis of specific room sizes. The STI calculator, for instance, states that its results are based on the average room size of 28 m^2 for North American hotels and 15 m^2 - for tourism accommodation establishments in Europe. It is however argued that the values of GHG emissions calculated on these parameters will not necessarily reflect the reality as the energy consumption per 1 m^2 of the room in many hotels may deviate from the calculator-specified figures, subject to the hotel quality and the range of services offered.

As for tourist activities, the analysis has revealed that this fundamental component of tourism is addressed by the carbon calculators to even a lesser extent than tourism accommodation (Table 4). The range of activities measured is rather small and the estimates significantly vary. Moreover, the origin of the figures is in all cases unknown. Having said this, it is important to note that some unique tourist activities offered for calculation of their GHG emissions are also available. The Clear Offset calculator, for instance, claims to be the only carbon calculator capable of measuring the carbon footprint of skydiving.

While the methodologies and data sources behind the GHG emissions factors employed by carbon calculators for tourist activities are unknown, they are deemed to differ as the produced estimates vary to a significant extent. Some methodological issues in calculations have been noticed: excursions are assessed with no differentiation in the excursion type. It is argued that the carbon footprint of excursions vary, depending on the means of transportation used, distance travelled and occupancy. The Cleaner Climate calculator only offers an option of measuring the GHG emissions from tours; these, in turn, include transport, accommodation and excursions. Finally, the Small World Consulting calculator (not covered in this review) measures the

GHG emissions of a hotel stay on the basis of spend. No explanation exists to how the monetary value is further converted to GHG emissions.

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APPENDIX 2. PUBLISHED MATERIAL PRODUCED IN RELATION TO THIS THESIS

Refereed journal papers

Filimonau, V., Dickinson, J. E., Robbins, D., and Reddy, M. V., 2011a. 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., Huijbregts, M. A. J., 2011b. 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, 1917-1930.

APPENDIX 3. TOURIST ACTIVITIES QUESTIONNAIRE (ELECTRONIC VERSION)

How long are you staying in HV Algarve?	1 week	10 days	11 days	2 weeks	2 weeks+
Are you here on the 'all-inclusive' or on 'self-catering' basis?		'All-inclusive'		'Self-catering'	

Did you dine outside during your stay in HV Algarve? **'To dine outside' means to eat (breakfast, lunch and/or dinner) in the restaurant/cafe located <u>outside of the Holiday Village</u>**
If yes, how many times and where?

I ate outside during my stay	**How many times?**	**Where?**	**I cooked myself in my apartment**	**I did <u>not</u> eat outside during my stay**
☐	☐		☐	☐

If speaking generally about your food consumption when on holidays, …	**Much less**	**Less**	**The same**	**More**	**Much more**
… do you reckon you consume more or less food compared to your dining habits at home?	☐	☐	☐	☐	☐

Did you rent a car during your stay in HV Algarve? This could have been, for instance, for exploring the surroundings, etc. If yes, what type and how much did you travel? Your best estimate would be fine.

Type of car	**How many times (days)?**	**Where did you drive?**	**Approx. how many km?**	**I did <u>not</u> rent a car during my stay**
	☐		**OR** ☐	☐

Did you go on any excursions or visit any local attractions (e.g. museums)? If yes, how many times and whe

Type of excursion (attraction visited)	**How many times?**	**Where did you go?**	**Means of transport?**	**I did <u>not</u> go on any excursions**
Excursions	☐			
Museums	☐			☐
Other attractions	☐			

Did you undertake any tourist activities? This can be, for example, paragliding, water skiing, boat cruise, rent of water scooter, etc.

Type of activities	**How many times?**	**Where?**	**Type of activities**	**How many times?**	**Where?**	**I did <u>not</u> undertake any activities**
1	☐		4	☐		
2	☐		5	☐		☐
3	☐		6	☐		

Where are you from in the UK? ___________________________ Please provide the first 3 letters of your postcode ___________ **What airport in the UK did you fly from?** _______________________________

How did you travel to the airport?	Car (on my own)	Car (with my family)	Subway	Bus	Coach	Train

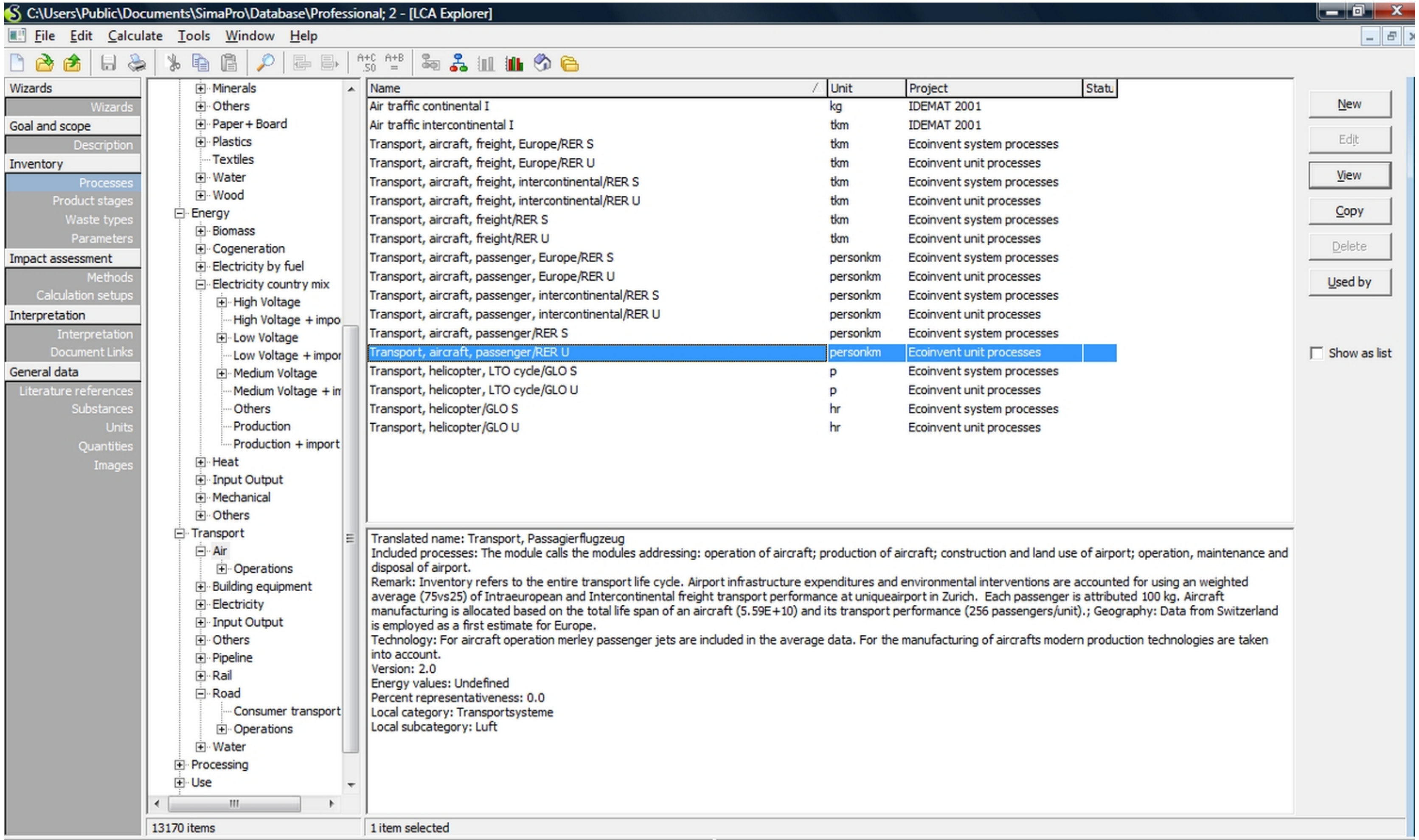
When leaving home, did you leave your electric appliances in a stand-by mode?	Yes, I did	Yes, part of them	No, I did not	I do not remember

Are you?	Female	Male

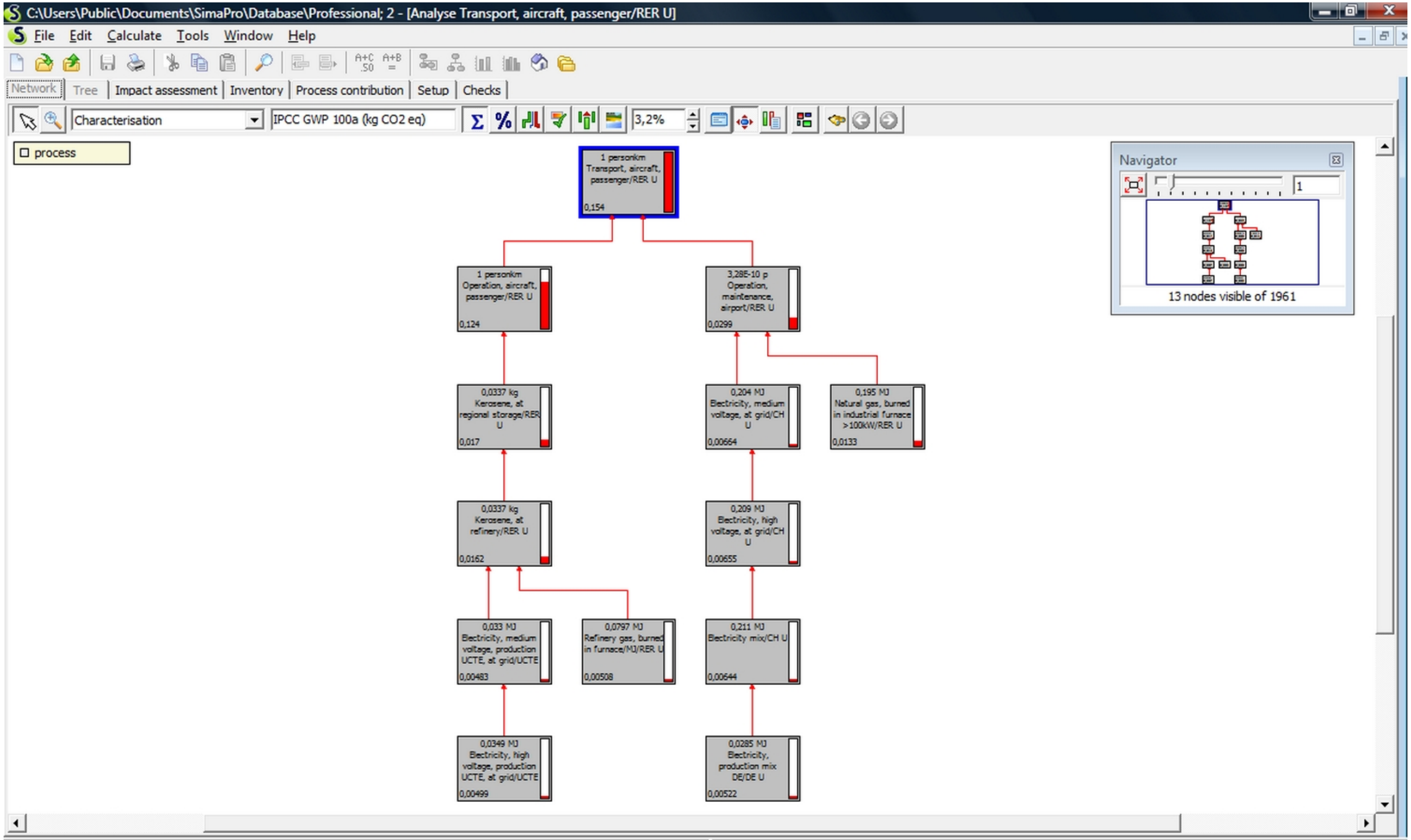
In which age group are you?	16-24	25-34	35-44	45-54	55-64	65-74	75+

APPENDIX 4. SIMAPRO 7.1 SOFTWARE (INTERFACE AND EXAMPLES OF ANALYSIS)

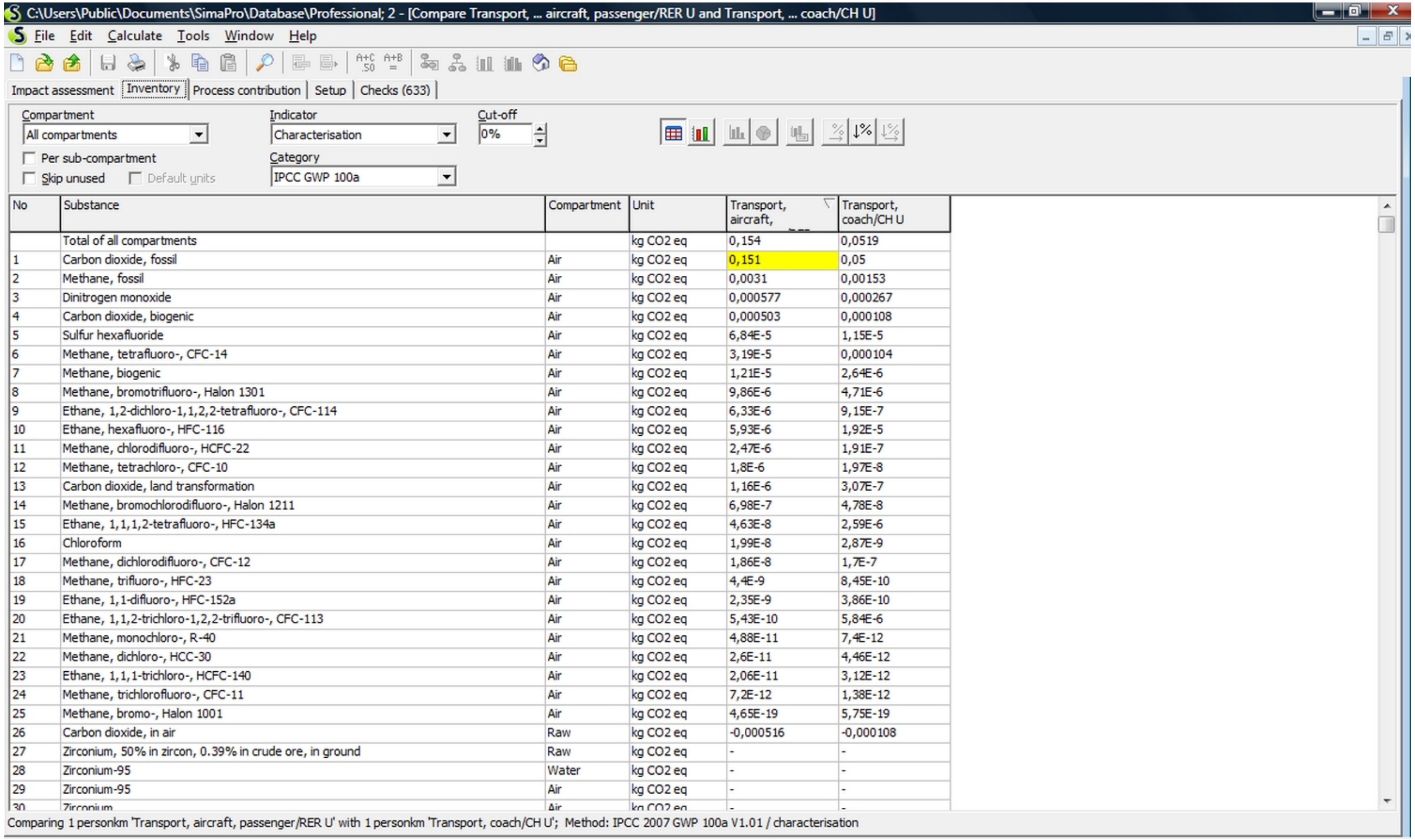
General software interface:



Analysis of the ‘average air transport’ category of air travel (see Table 7.10), contribution of different life cycle elements:



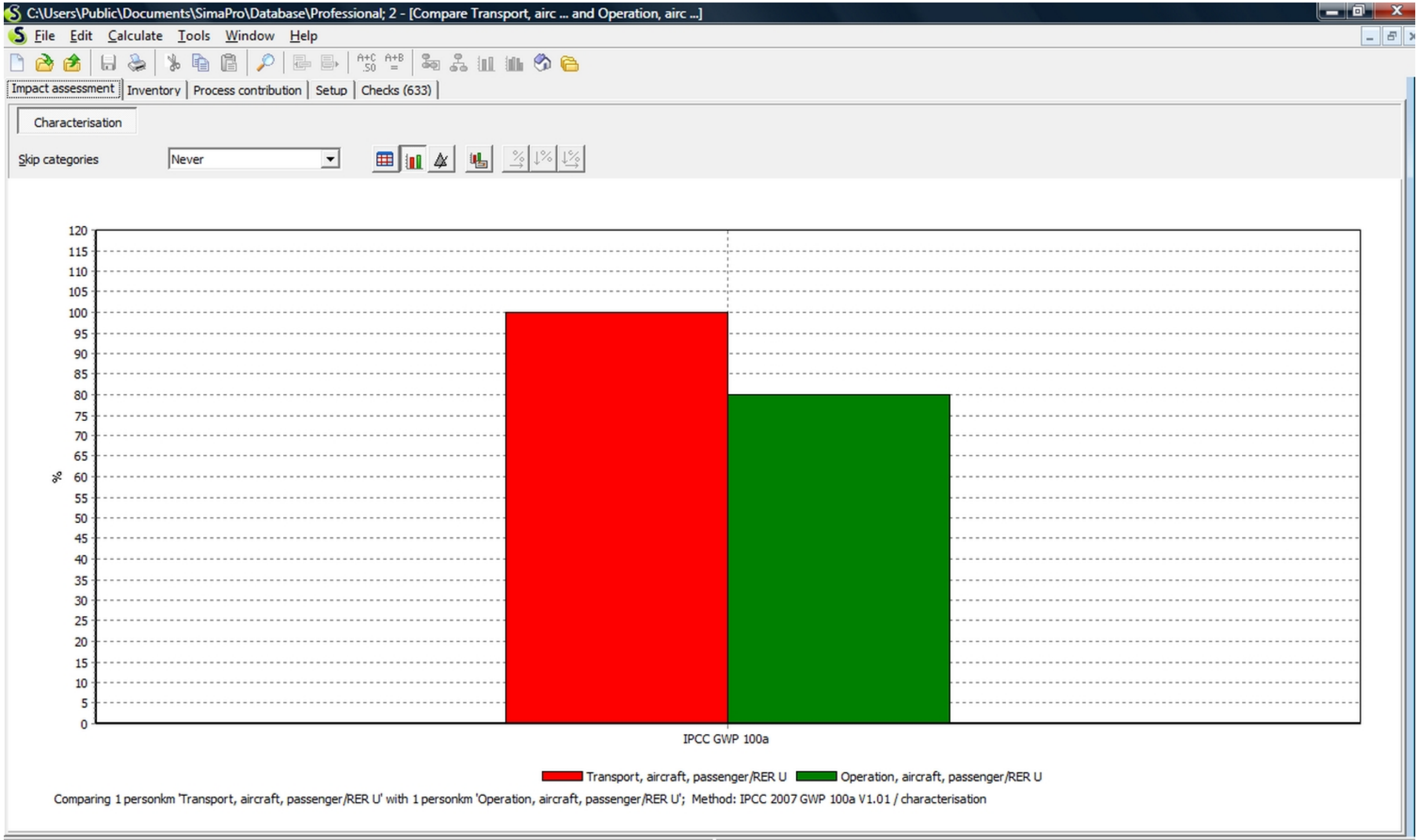
Comparison of the GHG emission inventories for ‘air travel’ and ‘coach travel’ transportation categories, contribution of different greenhouse gases:



No	Substance	Compartment	Unit	Transport, aircraft,	Transport, coach/CH U
	Total of all compartments		kg CO2 eq	0,154	0,0519
1	Carbon dioxide, fossil	Air	kg CO2 eq	0,151	0,05
2	Methane, fossil	Air	kg CO2 eq	0,0031	0,00153
3	Dinitrogen monoxide	Air	kg CO2 eq	0,000577	0,000267
4	Carbon dioxide, biogenic	Air	kg CO2 eq	0,000503	0,000108
5	Sulfur hexafluoride	Air	kg CO2 eq	6,84E-5	1,15E-5
6	Methane, tetrafluoro-, CFC-14	Air	kg CO2 eq	3,19E-5	0,000104
7	Methane, biogenic	Air	kg CO2 eq	1,21E-5	2,64E-6
8	Methane, bromotrifluoro-, Halon 1301	Air	kg CO2 eq	9,86E-6	4,71E-6
9	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	kg CO2 eq	6,33E-6	9,15E-7
10	Ethane, hexafluoro-, HFC-116	Air	kg CO2 eq	5,93E-6	1,92E-5
11	Methane, chlorodifluoro-, HCFC-22	Air	kg CO2 eq	2,47E-6	1,91E-7
12	Methane, tetrachloro-, CFC-10	Air	kg CO2 eq	1,8E-6	1,97E-8
13	Carbon dioxide, land transformation	Air	kg CO2 eq	1,16E-6	3,07E-7
14	Methane, bromochlorodifluoro-, Halon 1211	Air	kg CO2 eq	6,98E-7	4,78E-8
15	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	kg CO2 eq	4,63E-8	2,59E-6
16	Chloroform	Air	kg CO2 eq	1,99E-8	2,87E-9
17	Methane, dichlorodifluoro-, CFC-12	Air	kg CO2 eq	1,86E-8	1,7E-7
18	Methane, trifluoro-, HFC-23	Air	kg CO2 eq	4,4E-9	8,45E-10
19	Ethane, 1,1-difluoro-, HFC-152a	Air	kg CO2 eq	2,35E-9	3,86E-10
20	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	kg CO2 eq	5,43E-10	5,84E-6
21	Methane, monochloro-, R-40	Air	kg CO2 eq	4,88E-11	7,4E-12
22	Methane, dichloro-, HCC-30	Air	kg CO2 eq	2,6E-11	4,46E-12
23	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg CO2 eq	2,06E-11	3,12E-12
24	Methane, trichlorofluoro-, CFC-11	Air	kg CO2 eq	7,2E-12	1,38E-12
25	Methane, bromo-, Halon 1001	Air	kg CO2 eq	4,65E-19	5,75E-19
26	Carbon dioxide, in air	Raw	kg CO2 eq	-0,000516	-0,000108
27	Zirconium, 50% in zircon, 0.39% in crude ore, in ground	Raw	kg CO2 eq	-	-
28	Zirconium-95	Water	kg CO2 eq	-	-
29	Zirconium-95	Air	kg CO2 eq	-	-
30	Zirconium	Air	kg CO2 eq	-	-

Comparing 1 personkm 'Transport, aircraft, passenger/RER U' with 1 personkm 'Transport, coach/CH U'; Method: IPCC 2007 GWP 100a V1.01 / characterisation

Comparison of the ‘direct’ (operational only) and total (capital goods and infrastructure inclusive) GHG emissions from the ‘average air transport’ category of air travel:



APPENDIX 5. THE SURVEY ON TOURIST ACTIVITIES: AGGREGATE RESULTS.

Respondent code № / Type of activity	Duration of stay (nights)	Dining out (number of times)	Food consumption when on holidays compared to food consumption at home	Car rental (days)	Tourist activities: attractions	Tourist activities: entertainment	Tourist activities: activities	UK airport of arrival and departure	Main mode of travel to/from the airport in the UK	Stand-by mode	Gender	Age
1	10	2	=	-	5	-	-	Gatwick		No	M	35-44
2	14	3	=	-	7	-	-	Manchester	Car (with my family)	No	F	25-34
3	7	2	=	-	2	-	-	Gatwick		Do not remember	M	45-54
4	10	2	+	-	6	-	1		Train	Yes, partly	M	35-44
5	14	3	+	3	5	-	1	Manchester	Taxi	No	M	35-44
6	11	2	=	2	1	-	-	Gatwick	Car (with my family)	Do not remember	M	35-44
7	14	2	=	-	4	-	-	Birmingham	Taxi	No	F	35-44
8	10	-	+	-	3	-	-	Gatwick	Car (with my family)	No	F	45-54
9	7	-	+	-	-	-	3	Stansted	Taxi	Yes	F	25-34
10	14	2	=	-	4	-	1	Bristol		Yes	M	45-54
11	7	1	=	-	3	1	1			No	F	35-44
12	7	-	=	-	1	1	-		Car (with my family)	No	F	35-44
13	7	2	=	-	2	2	-			Do not remember	M	35-44
14	7	1	=	-	-	-	-			Yes, partly	F	25-34
15	14	2	=	-	6	-	-			Do not remember	F	35-44
16	7	-	=	-	3	2	-	Gatwick	Coach	Yes	F	25-34
17	14	5	=	3	1	3	-			Do not remember	F	35-44
18	14	2	=	-	6	-	1		Car (with my family)	No	F	35-44
19	14	2	=	3	4	-	-			Yes	M	35-44
20	14	2	=	-	2	-	1			No	M	35-44
21	14	5	=	-	1	1	1	Newcastle	Taxi	No	F	35-44
22	14	-	+	-	6	-	-	Birmingham		No	F	35-44
23	7	4	=	-	-	-	-	Bristol		No	F	35-44
24	7	-	=	-	-	-	-	Gatwick		Yes	F	25-34
25	11	-	=	-	7	-	-	Cardiff		Yes	F	35-44
26	14	-	=	-	-	-	-	Manchester	Car (with my family)	No	F	35-44
27	14	2	=	-	4	-	2	Birmingham		No	M	25-34
28	14	3	=	-	3	-	1	Doncaster		Do not remember	M	35-44
29	14	3	+	-	6	-	-	Manchester		No	F	25-34
30	14	3	+	-	5	-	-	Glasgow		No	F	25-34
31	7	6	=	-	1	-	-	Belfast		No	F	35-44
32	7	1	=	-	2	-	1			Yes	M	25-34
33	14	3	=	-	4	-	1	Gatwick	Coach	Do not remember	F	16-24
34	7	-	=	-	2	2	-		Coach	Yes	M	55-64
35	7	-	=	-	2	-	-	Glasgow		No	M	35-44
36	7	4	=	3	-	-	2	Bristol		Yes, partly	M	35-44
37	7	1	=	-	2	1	-		Car (with my family)	Yes, partly	F	35-44
38	7	-	=	-	2	-	-	Doncaster		Do not remember	F	25-34
39	7	1	=	-	1	3	-			Yes, partly	F	35-44
40	7	-	=	-	2	-	-	Gatwick	Coach	Yes	F	45-54
41	7	-	=	-	3	-	-		Car (with my family)	Yes	F	35-44
42	14	1	=	-	-	3	2	Manchester		Yes	M	35-44
43	7	2	+	2	3	-	-	Gatwick	Train	No	M	35-44

APPENDIX 6. LIST OF POPULAR TOURIST ACTIVITIES[1] IN ALBUFEIRA (PORTUGAL).

The 'Provider / Booking option' column lists the methods/agents, via which an activity can be obtained. For example, 'self-organisation' means that tourists can independently get to/from the place where an activity commences/is provided. 'HV Algarve' means that activities are booked via TUI Travel and/or at the hotel reception and provided by the HV Algarve contracting agents. 'ITO' stands for 'Independent Tour Operator' (i.e. tour operator and/or self-employed individual provider of tourist activities not affiliated with HV Algarve and/or TUI Travel).

Type of tourist activity	Location	Transportation options	Provider / Booking option
I. Attractions (all)			
among them	a) Attractions (amusement, family and theme parks)		
Aqualand family park	Algarve	Bus, taxi, car	HV Algarve; ITO; self-organisation
Aquashow family park	Algarve	Bus, taxi, car	HV Algarve; ITO; self-organisation
Omega zoo park	Algarve	Bus, taxi, car	HV Algarve; ITO; self-organisation
Slide & Splash aqua park	Algarve	Bus, taxi, car	HV Algarve; ITO; self-organisation
'Zoomarine' marine fauna complex	Algarve	Bus, taxi, car	HV Algarve; ITO; self-organisation
among them	b) Attractions (other)		
Beach	Albufeira or Santa Eulalia beach	Bus, taxi, car, walking	Self-organisation
Museum	Albufeira old town	Bus, taxi, car, walking	Self-organisation
II. Entertainment			
Bars, cafes, restaurants, shopping	Albufeira old town	Bus, taxi, car, walking	Self-organisation
Cinema	Albufeira old town	Bus, taxi, car, walking	Self-organisation
Night clubs, discos, casinos	Albufeira old town	Bus, taxi, car, walking	Self-organisation
III. Activities (all)			
among them	a) Motorised water activities		
Parasailing	Albufeira or Santa Eulalia beach	Bus, taxi, car, walking	ITO
Jet skiing	Albufeira or Santa Eulalia beach	Bus, taxi, car, walking	ITO
Boat cruise	Albufeira old town	Bus, taxi, car, walking	HV Algarve; ITO
Fishing tour	Albufeira old town	Bus, taxi, car, walking	HV Algarve; ITO
among them	b) Excursions		
Algarve and gypsy market	Algarve	Coach, car	ITO
Ancient Algarve	Algarve	Coach, car	ITO
Faro	Algarve	Coach, bus, taxi, car	HV Algarve; ITO; self-organisation
Gibraltar	Spain/UK	Coach, car	ITO
Granada, Seville	Spain	Coach, car	ITO
Lagos, Sagres and other nearby towns	Algarve	Coach, car	ITO
Lisbon	Portugal	Coach, car	ITO
Nature park Rio Formosa	Algarve	Coach, taxi, car	ITO; self-organisation
among them	c) Other activities		
Golf courses	Algarve	Coach, bus, taxi, car, walking	HV Algarve; ITO; self-organisation
Horse riding	Algarve	Coach, bus, taxi, car, walking	HV Algarve; ITO
Jeep safari	Algarve	Bus, taxi, car, walking	HV Algarve; ITO
Pedal and banana boats rent	Albufeira or Santa Eulalia beach	Bus, taxi, car, walking	ITO

[1] Categorisation of tourist activities is adapted from Becken and Simmons (2002).

APPENDIX 7. TOURIST ACTIVITIES UNDERTAKEN BY SURVEY RESPONDENTS IN ALBUFEIRA (PORTUGAL).

Table 1 presents the results of a survey on tourist activities in the Algarve. The data collected need some explanations:

Many respondents mentioned 'beach' as one of the tourist activities they undertook. While it is fair to assume that visiting a beach does not entail any direct GHG emissions, travel to the beach and activities undertaken on the beach can do.

The majority of respondents claimed that the beach they visited was situated in the vicinity of HV Algarve and was accessible either by walking (approximately 15-20 minutes) or by using a complimentary bus service provided by the hotel (circa 5 minutes). The use of taxi was another transportation option. As the beach referred to by interviewees is located not far away from the hotel complex, the nearest beach to HV Algarve, i.e. the Santa Eulalia beach, was used for distance calculations.

As for tourist activities undertaken on the beach, i.e. jet skiing and parasailing, only the number of those was counted. These activities were assigned the relevant values of carbon intensities when the final estimates of GHG emissions were made. The carbon footprint from traveling to/from the beach where these activities were undertaken was accounted for in the 'beach' tourist activity category, as described above.

Some respondents originally mentioned 'visits to Albufeira' among the tourist activities they undertook. These predominantly meant shopping visits. Hence, 'shopping' was listed as a primary tourist activity in Table 1 in the corresponding tourist activity category.

To calculate the distance related to shopping, the distance between HV Algarve and Albufeira old town was measured. Importantly, 'visits to Albufeira' as a tourist activity may also involve dining out, i.e. visits to bars, pubs and restaurants. These dining activities were not accounted for in Table 1; instead, they are listed and analysed in Table 1 Appendix 8 as interviewees were explicitly asked to separate their 'shopping' tourist activities from 'dining out' tourist activities. This was required to cover the whole range of tourist activities and, concurrently, to avoid double-counting of the related energy intensities and carbon footprints, also for travel to/from the place where activities were organised/took place.

Table 1. Tourist activities undertaken by survey respondents.

Grey colour indicates tourists who hired a car during their stay at HV Algarve. Distances are measured with the help of Google Maps (2011).

Respondent code	**Type of activity**	**Times**	***Total***	**Name of activity**	**Means of travel to where an activity is organised**	**Return distance (km)**	
							Total, single mode
1	Attraction	3	*5*	Beach	Walking	-	62
		1		Aquashow family park	Bus	35.6	
		1		'Zoomarine' complex		26.4	
2	Attraction	5	*7*	Beach, shopping	Walking	-	62
		1		Aquashow family park	Bus	35.6	
		1		'Zoomarine' complex		26.4	
3	Attraction	2	*2*	Beach	Walking	-	
4	Attraction	5	*7*	Beach	Walking	-	45
		1		Aquashow family park	Bus	35.6	
	Activity	1		Boat cruise		9.4	
5	Attraction	3	*6*	Beach	Walking	-	-
		1		Aquashow family park	Car	see Table 6.8	
		1		Slide & Splash aqua park			
	Activity	1		Parasailing	Walking	-	
6	Attraction	1	*1*	Slide & Splash aqua park	Car	see Table 6.8	-
7	Attraction	2	*4*	Beach	Bus	3	111.5
		1		Slide & Splash aqua park		66.7	
		1		Aqualand family park		38.8	
8	Attraction	3	*3*	Beach	Walking	-	-

9	Activity	3	*3*	Mini-golf	Onsite[1]	-	-
10	Attraction	3	*5*	Beach	Walking	-	-
		1		'Zoomarine' complex	Bus	26.4	26.4
	Activity	1		Gibraltar	Coach	854	854
11	Attraction	2	*5*	Beach	Walking	-	-
		1		'Zoomarine' complex	Bus	26.4	26.4
	Entertainment	1		Shopping	Taxi	9.4	9.4
	Activity	1		Algarve and gypsy market[2]	Coach	35.8	35.8
12	Attraction	1	*2*	Beach	Taxi	3	12.4
	Entertainment	1		Shopping		9.4	
13	Attraction	2	*4*	Beach	Walking	-	18.8
	Entertainment	2		Shopping	Taxi	9.4	
14	-	-	-	-	-	-	-
15	Attraction	3	*6*	Beach	Bus	3	137.7
		1		Aquashow family park		35.6	
		1		Slide & Splash aqua park		66.7	
		1		'Zoomarine' complex		26.4	
16	Attraction	3	*5*	Beach	Walking	-	18.8
	Entertainment	2		Shopping	Taxi	9.4	
17	Entertainment	3	*4*	Shopping	Taxi	9.4	28.2
	Attraction	1		'Zoomarine' complex	Bus	26.4	26.4

[1] Although two interviewees mentioned mini-golf and sport as tourist activities they undertook, they partook in both at HV Algarve, i.e. onsite. Therefore any energy consumption involved into provision of these tourist activities should have been accounted for in the hotel's annual energy bills.

[2] Precise location of the market was not specified by an interviewee. As there are many gypsy markets in the Algarve, it was assumed that one of the biggest markets in the region, i.e. the Quarteira gypsy market, was visited.

18	Attraction	5	*7*	Beach	Bus	3	81.7
		1		Slide & Splash aqua park		66.7	
	Activity	1		Seville	Coach	460	460
19	Attraction	3	*4*	Beach	Walking	-	-
		1		'Zoomarine' complex	Car	see Table 6.8	
20	Attraction	2	*3*	Beach	Bus	3	6
	Activity	1		Jeep safari	Taxi	9.4	9.4
21	Attraction	1	*3*	Aquashow family park	Bus	35.6	54.4
	Activity	1		Boat cruise		9.4	
		1		Jeep safari		9.4	
22	Attraction	5	*6*	Beach	Walking	-	35.6
		1		Aquashow family park	Bus	35.6	
23	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-
25	Attraction	5	*7*	Beach, shopping	Taxi	9.4	9.4
		1		Aquashow family park	Bus	35.6	62
		1		'Zoomarine' complex		26.4	
26	-	-	-	-	-	-	-
27	Attraction	4	*6*	Beach	Walking	-	-
	Activity	1		Parasailing			
		1		Jet skiing			
28	Attraction	2	*4*	Beach	Bus	3	32.4
		1		'Zoomarine' complex		26.4	
	Activity	1		Jeep safari	Taxi	9.4	9.4
29	Attraction	4	*6*	Beach	Walking	-	65.2
		1		Aqualand family park	Bus	38.8	
		1		'Zoomarine' complex		26.4	

30	Attraction	4	*5*	Beach	Walking	-	26.4
		1		‘Zoomarine’ complex	Bus	26.4	
31	Attraction	1	*1*	Beach	Taxi	3	3
32	Attraction	2	*3*	Beach	Walking	-	32.8
	Activity	1		Vilamoura town	Bus	32.8	
33	Attraction	3	*5*	Beach	Walking	-	35.6
		1		Aquashow family park	Bus	35.6	
	Activity	1		Boat cruise	Taxi	9.4	9.4
34	Attraction	2	*4*	Beach	Bus	3	6
	Entertainment	2		Shopping	Taxi	9.4	18.8
35	Attraction	2	*2*	Beach	Taxi	3	6
36	Activity	2	*2*	Sport	Onsite	-	-
37	Attraction	2	*3*	Beach	Bus	3	6
	Entertainment	1		Shopping	Taxi	9.4	9.4
38	Attraction	2	*2*	Beach	Bus	3	6
39	Attraction	1	*4*	Beach	Walking	-	28.2
	Entertainment	3		Shopping	Taxi	9.4	
40	Attraction	2	*2*	Beach	Walking	-	-
41	Attraction	2	*3*	Beach	Walking	-	3
		1		Beach	Bus	3	
42	Entertainment	3	*4*	Shopping	Taxi	9.4	28.2
	Activity	1		Albufeira, Lagos, Sagres	Coach	178.2	178.2
43	Attraction	3	*3*	Beach	Walking	-	-
TOTAL			***158***				

The ‘entertainment’ category of tourist activities includes visits to bars, cafes and restaurants. The GHG emissions related to these visits will be accounted for in the ‘dining’ category of analysis.

For such tourist activities as ‘jeep safari’ and ‘boat cruise’ it was assumed that they commenced/were organised in Albufeira old town. This suggests travel to/from Albufeira. Hence, the distance between HV Algarve and Albufeira old town was measured. The means of transport was also specified.

In the case of excursions and some attractions (amusement, family and theme parks), it was observed that tourists were picked up by bus/coach right outside HV Algarve as the resort is located in direct proximity (circa 100 m) to the major road linking Albufeira to Faro. This suggests that no additional travel was required for tourists to get to/from Albufeira and, hence, there was no extra carbon footprint related to travel.

Those tourists who hired a car during their stay in the Algarve and concurrently partook in tourist activities were asked to specify if a hired car was used to get to/from the place where tourist activities were organised. If so, the data on distances driven by a hired car from Table 6.8 were used for final carbon footprint assessment of respective tourist activities to avoid double-counting.

Data analysis

Analysis shows that most respondents (91%) undertook at least one tourist activity during their stay at HV Algarve. If the total number of tourist activities undertaken by the survey sample is divided by the number of interviewees, the average value of 3.7 tourist activities per respondent is obtained.

The popularity of different tourist activities varies (Table 2), although beach visits (‘attraction’ category) are clearly on the top. These were mentioned by 79% of all respondents. If the average number is calculated, at least 2 beach visits were undertaken by each interviewee.

The second most popular tourist activity also comes from the ‘attraction’ category and is represented by visits to ‘Zoomarine’ marine fauna complex, mentioned by 26% of all interviewees. In total, due to the high popularity of visits to the beach and amusement parks, the ‘attraction’ category of tourist activities dominates over the others, with 2.8 attractions visited, on average, by each interviewee.

Table 2. Popularity of tourist activities with survey respondents.

Activity type	Activity name	Frequency of responses (% of all respondents)	Total number of times visited/undertaken	Average, per respondent
Attraction (all)			***121***	***2.8***
		Amusement	*27*	*0.63*
among them	'Zoomarine'	11 (26%)		
	Aquashow	9 (21%)		
	Slide & Splash	5 (12%)		
	Aqualand	2 (5%)		
		Other	*94*	*2.19*
among them	Beach	34 (79%)		
Entertainment			**18**	**0.42**
	Shopping	9 (21%)	*18*	*0.42*
Activities (all)			**19**	**0.44**
		Motorised water activities	*6*	*0.14*
among them	Boat cruise	3 (7%)		
	Parasailing	2 (5%)		
	Jet skiing	1 (2%)		
		Excursions	*5*	*0.12*
among them	Gibraltar	1 (2%)		
	Seville	1 (2%)		
	Algarve and gypsy market	1 (2%)		
	Albufeira, Lagos, Sagres	1 (2%)		
	Vilamoura town	1 (2%)		
		Other	*8*	*0.19*
among them	Jeep safari	3 (7%)		
	Mini-golf	1 (2%)		
	Sport	1 (2%)		
		TOTAL	158	3.7

The 'entertainment' category of tourist activities is the least popular, with only every fifth respondent partaking in these. The explanation is that shopping was reported as the only activity within this category. Although there are plenty of small souvenir shops in Albufeira, there are no big shopping malls. This may partially explain why shopping was not very popular with survey respondents. In addition, the 'entertainment' category of tourist activities also includes bar/night club/disco/casino visits. It is deemed that these activities are more popular with younger tourists. Since most interviewees are 35+ year old, this may serve as another explanation.

The popularity of the 'activity' category is also rather low. Again, the age factor may play a role here. Importantly, despite a small number of 'activities' undertaken by interviewees, many of them can have significant carbon footprints which has important implications for the total GHG emissions from the holiday package.

The analysis indicates that the frequency of tourist activities undertaken by interviewees correlates with their duration of stay (Figure 1, Table 3). Holidaymakers with a longer stay were more active participants in tourist activities. For example, the 14-night tourists partook, on average, in almost 5 tourist activities, while the 7-night tourists undertook less than 3. This finding is in line with the conclusions by Becken (2008) who argue that tourists staying at the destination longer have a tendency to undertake more activities and visit more places than holidaymakers with shorter durations of stay. This is arguably because tourists staying at the destination longer have more time to participate in tourist activities. In addition, it is deemed that the willingness of tourists to experience something new is another explanation as a long stay in the similar environment (for instance, a hotel complex) may cause boredom. In the case of HV Algarve, for example, despite a variety of the onsite entertainment facilities and amusement options available to the hotel guests, some interviewees reported that these were rather repetitive and predominantly children-oriented. This may explain why respondents with a longer duration of stay had a tendency to leave the hotel more often and partake in more tourist activities.

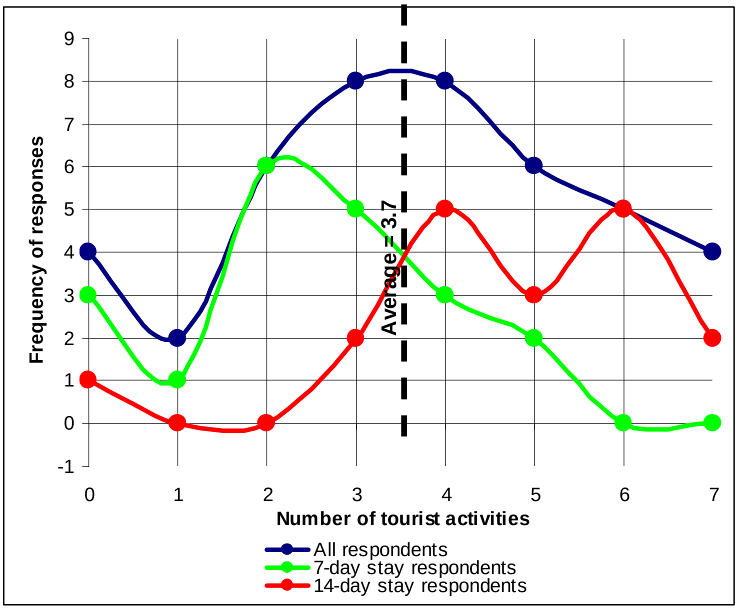


Figure 1. Frequency of tourist activities undertaken by survey respondents.

Table 3 shows that those interviewees who stayed at HV Algarve 14 nights are responsible for 54% of the total number of tourist activities undertaken by survey respondents. In contrast, interviewees who stayed at the hotel complex for 7 nights took part only in 32% of the reported activities although the number of the latter tourists in the survey sample is larger. Importantly, if tourist activities are averaged per day of stay, there is literally no difference in the frequency of the undertaken activities between 7 and 14-night staying holidaymakers (Table 3). Although the analysis indicates that tourists undertake equal number of activities per day of stay, it is argued that long staying holidaymakers may partake in a larger number of more energy-intense activities than tourists with shorter durations of stay.

Table 3. Number of tourist activities undertaken versus duration of stay.

Activity type	Activity name / Duration of stay (days/nights)	7	10	11	14
Attractions (all)		**121**			
Amusement		*27 (100%)*			
	'Zoomarine'	1 (4%)	1 (4%)	1 (4%)	8 (30%)
	Aquashow	-	2 (7%)	1 (4%)	6 (22%)
	Slide & Splash	-	-	1 (4%)	4 (14%)
	Aqualand	-	-	-	2 (7%)
Other		*94 (100%)*			
	Beach	30 (32%)	11	5 (5%)	48 (51%)
Entertainment		**18**			
	Shopping	12 (67%)	-	-	6 (33%)
Activities (all)		**19**			
Motorised water activities		*6 (100%)*			
	Boat cruise	-	1 (17%)	-	2 (33%)
	Parasailing	-	-	-	2 (33%)
	Jet skiing	-	-	-	1 (17%)
Excursions		*5 (100%)*			
	Gibraltar	-	-	-	1 (20%)
	Seville	-	-	-	1 (20%)
	Algarve and gypsy market	1 (20%)	-	-	-
	Albufeira, Lagos, Sagres	-	-	-	1 (20%)
	Vilamoura town	1 (20%)	-	-	-
Other		*8 (100%)*			
	Jeep safari	-	-	-	3 (37%)
	Mini-golf	3 (37%)	-	-	-
	Sport	2 (26%)	-	-	-
TOTAL	158 (100%)	50 (32%)	15 (9%)	8 (5%)	85 (54%)
AVERAGE	per respondent from each category	2.5	5	4	4.7
	per day of stay for respondents from each category	0.36	0.5	0.37	0.34

The more active participation of the long-staying holidaymakers in tourist activities is particularly noticeable in the 'amusement' sub-category of tourist attractions, where interviewees with 14 nights of stay were responsible for 85% of the total number of activities. If tourists staying at HV Algarve 10 and 11 nights are added to this picture, the overall share increases to 96%.

Similar situation can be observed in the 'activity' category of tourist activities. Here, tourists staying at HV Algarve for 14 nights reported participation in 58% of all activities while the 7-night interviewees partook in 37%. More importantly is that, in carbon footprint terms, respondents with a longer duration of stay should have generated the dominant portion of carbon impacts attributed to this activity category as they undertook the majority of those activities which are very energy-intense, i.e. boat cruises, jeep safaris and parasailing, and long-distance excursions with consequent significant GHG emissions (Table 3).

Travel related to tourist activities

To estimate the carbon footprint from local transportation at the destination which relates to tourist activities, the total distances covered by different transport modes were measured. Since walking did not entail direct GHG emissions, it was excluded from analysis. The distances covered by a rented car were also not considered as the associated carbon impacts were estimated in the 'car rental' category of tourist activities (data from Table 6.8).

Table 4 shows that the total, tourist activities-related, distance traveled by interviewees is significant, representing 37% of the distances travelled by respondents to get to/from the airport in the UK. This finding is rather surprising as local travel at the destination is usually considered to be negligible.

Table 4. Distances travelled by survey respondents to partake in tourist activities.

Travel mode	Min return distance (km)	Max return distance (km)	Total return travelled distance (km)	Average return distance (km), per respondent
Bus	3	137.7	905.5	21.1
Coach	35.8	854	1528	35.5
if journeys to Gibraltar and Seville are excluded	*35.8*	*178.2*	*214*	*5*
Tax	3	28.2	218.8	5.1
For all modes	**3**	**854**	**2652.3**	**61.7**

The primary contribution to this distance was made by the two long-haul coach journeys to Gibraltar and Seville. These were responsible for 1314 km travelled which corresponds to 50% of the total distances covered. If these two trips are excluded, the local travel at the destination is still equal to 18% of the distances covered by interviewees to get to/from airport in the UK.

If the average return distances are calculated per tourist, the results indicate that coach travel has the largest distance, while taxi – the smallest (Table 4). If two long-haul coach journeys are however excluded from analysis, the average return distance of coach travel, per respondent, equates to only 5 km.

As for the most popular mode of travel to get to/from the place where tourist activities commenced/were organised, bus and walking were on the top (Table 5). A high popularity of walking is due to the proximity of the beach, the most popular tourist activity among interviewees. About every second tourist activity involved getting to the place where it commenced/was organised on foot. Taxi was the most popular means of transportation for 'shopping' as Albufeira old town, the primary shopping destination, is situated quite far away from the hotel complex (return distance is 9.4 km) and cannot be easily accessed on foot, especially with children. Bus is an equally popular mode of travel to get to/from the beach and for shopping. In the latter case it can be explained by its low costs, while in the former – by the free provision of bus services by HV Algarve to its guests.

Table 5. Popularity of different transport modes to get to/from the place where tourist activities commenced/were organised in the Algarve.

Frequency / Travel mode	**Walking**	**Bus**	**Taxi**	**Coach**	**Car**
Number of respondents	21	22	15	4	3
% of respondents	*49*	*51*	*35*	*6*	*7*
Number of tourist activities	67	48	30	4	4
% of activities[1]	*42*	*30*	*19*	*3*	*3*
Average number of tourist activities per travel mode	0.42	0.3	0.2	0.03	0.03

It is acknowledged that the results of this analysis of tourist activities in the Algarve must be taken with caution. In addition to a relatively small sample size of the survey, another limitation of this study is that different tourists may have had different understanding of what stood behinds the term 'a tourist activity'. Many interviewees referred to the 'beach' as to one of the tourist activities, although it is not present on the traditional classification list of tourist activities (see, for example, Becken and Simmons 2002). Some tourists, for instance, perceived sport activities as a tourist activity (respondent code 36) while others may have accepted it as a daily routine and therefore did not mention it in the survey. This survey employed the categorisation of tourist activities from Becken and Simmons (2002) but it is deemed that more research on how tourist activities are understood by holidaymakers would clarify this point.

[1] Five tourist activities (two for sport and three for mini-golf) took place at HV Algarve and therefore did not involve any travel.

APPENDIX 8. DINING PATTERNS OF SURVEY RESPONDENTS IN ALBUFEIRA (PORTUGAL).

The survey results demonstrate that, despite the AI nature of holidays, tourists tend to also dine outside the hotel (Table 1). Only 13 interviewees (circa 30%) claimed they did not dine outside HV Algarve, while the rest did this at least once. The maximum number of 'eating-out' was reported as 6, with the average value of 1.7 calculated for the whole sample of respondents. Importantly, two of those interviewees who ate out a significant number of times (i.e. respondent codes 31 and 36, 6 and 4 times respectively) complained about the quality of food in the hotel. This may partially explain their tendency to frequently dine out. At the same time, the majority of respondents did not express any dissatisfaction with regard to the food served at HV Algarve. Hence, if these two interviewees are excluded from analysis assuming that their answers do not represent the normal dining habits due to the food quality issue, the average number of 'eating-out' for the survey sample is 1.5 per respondent.

As for the location to dine out, the majority preferred the nearby restaurants (mentioned by 22 or 51% respondents) and aqua, family and entertainment parks (9 or 21%).

Similar to tourist activities, there is a relatively good correlation between the number of eating-outs and duration of stay at HV Algarve (Figure 1; Table 2). The average number of eating-outs equates 1.25 for tourists staying 7 days, 1.6 – for tourists staying 10 and 11 days, and 3.1 – for tourists staying 14 days. This finding is in line with the argument by Becken (2008) who found that a longer stay at tourist destination involves more activities, with food consumption being one of them, and may thus result in a higher carbon footprint.

Apart from time availability, another possible explanation to more frequent eating out among tourists with a longer duration of stay is the need for change, as tourists staying at the destination longer may be willing to experience something new. This may take the form of, for example, tasting new food since the one served at the hotel complex is often repetitive and can therefore be perceived boring and/or not diverse enough. This issue was repeatedly mentioned by interviewees when asking for reasons to dine out. This is also a result of more activities undertaken outside the hotel complex (for example, beach activities and visits to aqua and entertainment parks) as correlation between the frequencies of tourist activities and the duration of stay was found (see Figure 1 Appendix 7).

Table 1. Dining patterns of survey respondents. Bold numbers indicate interviewees who expressed dissatisfaction with the quality of food served in the hotel complex. Grey colour indicates respondents who hired a car during their stay.

Respondent code	Dining out (times)	Where	Means of travel to where food was consumed (times)	Return distance (km)	
				Total, single mode	
1	2	'Zoomarine	Bus	See Table 1 Appendix 7	
		Aquashow			
2	3	Albufeira old towr	Taxi (all 3 times	9.4	28.2
3	2	Beach	Walking	-	
4	2	Boat cruise	-	See Table 1:	
		Beach	Walking	-	
5	3	Albufeira old towr	Taxi (3)	9.4	28.2
6	2	Faro	Car (2)	See Table 6.8	
		Slide & Splash			
7	2	Aqualand	Bus (2)	See Table 1 Appendix 7	
		Slide & Splash			
8	-	-	-	-	
9	-	-	-	-	
10	2	Albufeira old towr	Taxi (2)	9.4	18.8
11	1	'Zoomarine	Bus	See Table1 Appendix 7	
12	-	-	-	-	
13	2	Restaurant nearby	Walking (2)	-	
14	1	Albufeira old towr	Bus	9.4	9.4
15	2	Albufeira old towr	Taxi (2)	9.4	18.8
16	-	-	-	-	
17	5	Different locations, mostly Albufeira old town	Car (5)	See Table 6.8	
18	2	Albufeira old towr	Taxi (2)	9.4	18.8
19	2	Albufeira old towr	Taxi (2)	9.4	18.8
20	2	Albufeira old town	Taxi (2)	9.4	18.8
21	5	Albufeira old towr	Taxi (4)	9.4	37.6
		Jeep safari	-	See Table1 Appendix 7	
22	-	-	-	-	
23	4	Albufeira old towr	Taxi (4)	9.4	37.6
24	-	-	-	-	
25	**-**	-	-	-	
26	-	-	-	-	
27	2	Albufeira old towr	Taxi (2)	9.4	18.8
28	3	Albufeira old towr	Tax	9.4	9.4
		Jeep safari	-	See Table1 Appendix 7	
		Restaurant nearby	Walking	-	
29	3	Albufeira old town (2)	Taxi (2)	9.4	18.8
		'Zoomarine	Bus	See Table1 Appendix 7	
30	3	Albufeira old town (2)	Taxi (2)	9.4	18.8
		'Zoomarine	Bus	See Table1 Appendix 7	
31	**6**	**Albufeira old town**	**Taxi (6)**	**9.4**	**56.4**
32	1	Vilamoura	Bus	See Table1 Appendix 7	
33	3	Albufeira old town (2)	Taxi (2)	9.4	18.8
		Aquashow	Bus	See Table1 Appendix 7	
34	-	-	-	-	
35	-	-	-	-	
36	**4**	**Albufeira old town**	**Car (3), taxi (1)**	**see Table 6.8**	**9.4**
37	**1**	**Albufeira old town**	**Taxi**	See Table1 Appendix 7	
38	-	-	-	-	
39	1	Albufeira old towr	Tax	See Table1 Appendix 7	
40	-	-	-	-	
41	-	-	-	-	
42	1	Albufeira old towr	Taxi	See Table1 Appendix 7	
43	2	Albufeira old towr	Car (2)	See Table 6.8	
		Faro			
TOTAL	**74**				

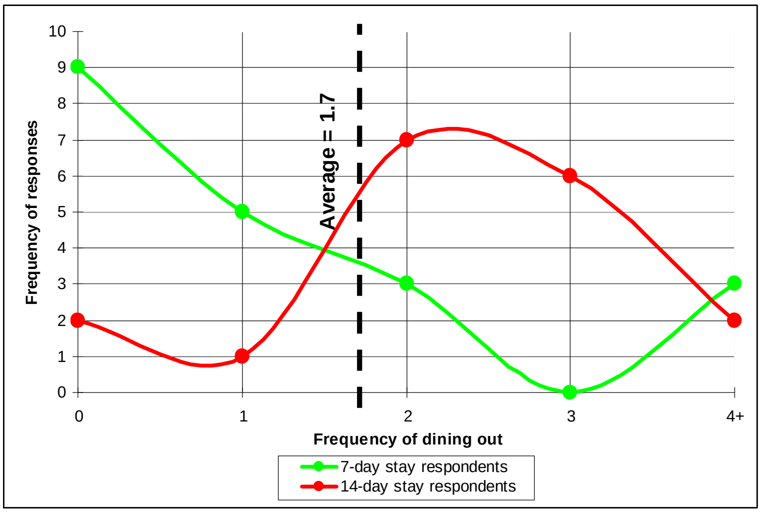


Figure 1. Frequency of dining out vs. duration of stay.

Table 2. Frequency of eating-out vs. duration of stay. The number of asterisks indicates how many interviewees from a specific category 'duration of stay' complained about the quality of food at HV Algarve.

Number of eating out (times) / Duration of stay (days	7	10	11	14
0	9	1	1*	2
1	5*	-	-	1
2	3	2	1	7
3	-	-	-	6
4 and more	3**	-	-	2
TOTAL number of respondent	**20**	**3**	**2**	**18**
AVERAGE per day of stay for respondents from each category	**0.14**	**0.1**	**0.09**	**0.07**

Importantly, all those tourists who rented a car dined outside of HV Algarve more frequently (Table 1). This is rather self-explanatory as driving a car involves traveling long distances which implies that car users are more likely to dine out. For this category of tourists, the average number of eating-outs equates 3 times, regardless of the duration of their stay. Importantly, when the number of dining out is averaged per day of stay for tourists from different lengths of stay, the results indicate that holidaymakers with 7 days of stay eat out more actively (Table 2).

Some interviewees pointed out that, apart from the food consumed at HV Algarve on the AI basis and food eaten outside the hotel, they also cooked in their apartments [1]. Theoretically, this food consumption should also contribute to the total carbon footprint from holiday travel. However, it was not included into analysis of the individual energy use and consequent GHG emissions from respondents as the energy required for food preparation in tourist apartments is already reflected in the energy bill of HV Algarve.

[1] Although this dining option was more popular with SC tourists rather than with AI tourists, a few AI holidaymakers did also mention it.

Energy bills are used to assess the carbon intensity of hotel stay, thus the energy and carbon footprint related to cooking at the hotel will be accounted for in the 'tourism accommodation', rather than in the 'tourist activities', impact category.

The carbon footprint from dining outside HV Algarve consists of 2 major elements [2]:

1) carbon footprint from food preparation and

2) carbon footprint from travel to/from the place where food is consumed.

To quantify the first element, the carbon intensity coefficients attributable to food preparation in cafés/restaurants retrieved from the literature will be used. This is because the 'real life' measurements were not feasible. To quantify the second element, tourists were asked to provide details of their travel to/from cafes/restaurants. The corresponding travel distances were further calculated with the help of Google Maps.

When calculating distances related to food consumption, all responses were thoroughly analysed and compared with the distances listed in previous tables (Table 6.8, Table 1 Appendix 7). This is because many interviewees dined out while undertaking tourist activities and/or when renting a car. For those respondents who hired a car during their stay and mentioned that they dined out on one of the days when a car was hired, it was assumed that car was used to get to/from the restaurant. Hence, the estimates of driving distances from the car rental dataset (Table 6.8) were taken. For those interviewees who partook in tourist activities and claimed that food was consumed during these activities, the distances from the tourist activities inventory (Table 1 Appendix 7) were utilised. For the final carbon footprint analysis, only the GHG emissions from car use and tourist activities-related travel will be calculated for these categories of respondents. This is necessary in order to avoid double-counting of the GHG emissions. The distances covered by walking were not estimated as there is no direct carbon footprint involved.

The analysis shows that taxi is the primary transport mode used by survey respondents for dining out, while bus was reported only once (Table 3). It is deemed that respondents had a tendency to eat out in the evening, when the bus schedules were infrequent. Moreover, taxi is a more convenient means of travel for families; hence the partial explanation to its popularity. While the total distances travelled to dine out

[2] GHG emissions related to food production and delivery were not quantified due to the lack of data. It is acknowledged that this additional carbon impacts can be significant.

appear to be insignificant compared to the distances covered to get to/from airport in the UK (5%) and to undertake tourist activities in Algarve (14%), some respondents travelled relatively long distances in total (for example, 56.4 km, respondent code 31). If the average distance is calculated for the whole sample of interviewees, the result is 8.7 km for taxi rides. The average distance covered by bus is negligible.

Table 3. Transport modes for dining out in Algarve.

Travel mode	Min return distance (km)	Max return distance (km)	Total return travelled distance (km)	Average return distance (km), for all respondents
Bus[3]	9.4	N/A	9.4	0.2
Taxi	9.4	56.4	376	8.7

[3] This number does not include bus journeys made in order to undertake tourist activities, see explanations in text.

APPENDIX 9. GHG EMISSIONS FROM TOURIST ACTIVITIES IN ALBUFEIRA (PORTUGAL), SAMPLE-AGGREGATE ESTIMATES PRODUCED BY DIFFERENT METHODS

Table 1. The total carbon footprint from tourist activities (kg of CO_2-eq.); aggregate data; estimates are by the **Ecoinvent (LCA/LCEA)** method.
Only carbon-producing tourist activities are analysed. The numbers in brackets indicate the 'direct' GHG emissions only.

№	Tourist activities: attractions	Carbon intensity	Tourist activities: entertainment	Carbon intensity-	Tourist activities: activities	Carbon intensity	Transport								Dining out	Carbon intensity	**Total GHG emissions**
							Bus		Coach		Car rental		Taxi				
							km	kg	km	kg	km	kg	km	kg			
1	1 1	1.51 1 **2.51**	-	-	-	-	62	**6.4**	-	-	-	-	-	-	2	1.3 **2.6**	**11.5** *(11)*
2	1 1	1.51 1 **2.51**	-	-	-	-	62	**6.4**	-	-	-	-	28.2	**2.7**	3	1.3 **3.9**	**15.5** *(14.4)*
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.3 **2.6**	**2.6** *(2.6)*
4	1	**1.51**	-	-	1	**18**	45	**4.7**	-	-	-	-	-	-	2	1.3 **2.6**	**26.8** *(26.4)*
5	1 1	1.51 1 **2.51**	-	-	1	**18**	-	-	-	-	202.3	**21.6**	28.2	**2.7**	3	1.3 **3.9**	**48.7** *(44.4)*
6	1	**1**	-	-	-	-	-	-	-	-	132.5	**14.2**	-	-	2	1.3 **2.6**	**17.8** *(15.3)*
7	1 1	1.51 1 **2.51**	-	-	-	-	111.5	**11.6**	-	-	-	-	-	-	2	1.3 **2.6**	**16.7** *(15.6)*
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1	**1**	-	-	1	-	26.4	**2.7**	854	**25.2**	-	-	18.8	**1.8**	2	1.3 **2.6**	**33.3** *(29.7)*
11	1	**1**	1	**0.59**	1	-	26.4	**2.7**	35.8	**1.1**			9.4	**0.9**	1	**1.3**	**7.6** *(7)*
12	-	-	1	**0.59**	-	-	-	-	-	-	-	-	12.4	**1.2**	-	-	**1.8** *(1.5)*
13	-	-	2	0.59 **1.2**	-	-	-	-	-	-	-	-	18.8	**1.8**	2	1.3 **2.6**	**5.6** *(5.2)*
14	-	-	-	-	-	-	9.4	**1**	-	-	-	-	-	-	1	**1.3**	**2.3** *(2.2)*
15	1 2	1.51 1 **3.51**	-	-	-	-	137.7	**14.3**	-	-	-	-	18.8	**1.8**	2	1.3 **2.6**	**22.2** *(20.6)*
16	-	-	2	0.59 **1.2**	-	-	-	-	-	-	-	-	18.8	**1.8**	-	-	**3** *(2.6)*
17	1	**1**	3	0.59 **1.8**	-	-	26.4	**2.7**	-	-	400	**42.8**	28.2	**2.7**	5	1.3 **6.5**	**57.5** *(49.1)*
18	1	**1**	-	-	1	-	81.7	**8.5**	460	**13.6**	-	-	18.8	**1.8**	2	1.3 **2.6**	**27.5** *(24.7)*
19	1	**1**	-	-	-	-	-	-	-	-	300	**32.1**	18.8	**1.8**	2	1.3 **2.6**	**37.5** *(31.4)*

20	-	-	-	-	1	**15.5**	6	**0.6**					28.2	**2.7**	2	1.3 **2.6**	**21.4** *(20.8)*
21	1	**1.51**	-	-	1 1	18 15.5 **33.5**	54.4	**5.7**	-	-	-	-	37.6	**3.5**	5	1.3 **6.5**	**50.7** *(49.5)*
22	1	**1.51**	-	-	-	-	35.6	**3.7**	-	-	-	-	-	-	-	-	**5.2** *(4.9)*
23	-	-	-	-	-	-	-	-	-	-	-	-	37.6	**3.5**	4	1.3 **5.2**	**8.7** *(8.1)*
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	1 1	1 1.51 **2.51**	-	-	-	-	62	**6.4**	-	-	-	-	9.4	**0.9**	-	-	**9.8** *(9.1)*
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	2	18 **36**	-	-	-	-	-	-	18.8	**1.8**	2	1.3 **2.6**	**40.4** *(40)*
28	1	**1**	-	-	1	**15.5**	32.4	**3.4**	-	-	-	-	18.8	**1.8**	3	1.3 **3.9**	**25.6** *(24.9)*
29	1 1	1 1.51 **2.51**	-	-	-	-	62.5	**6.8**	-	-	-	-	18.8	**1.8**	3	1.3 **3.9**	**15** *(14)*
30	1	**1**	-	-	-	-	26.4	**2.7**	-	-	-	-	18.8	**1.8**	3	1.3 **3.9**	**9.4** *(8.8)*
31	-	-	-	-	-	-	-	-	-	-	-	-	59.4	**5.6**	6	1.3 **7.8**	**13.4** *(12.4)*
32	-	-	-	-	1	-	32.8	**3.4**	-	-	-	-	-	-	1	**1.3**	**4.7** *(4.4)*
33	1	**1.51**	-	-	1	**18**	35.6	**3.7**	-	-	-	-	28.2	**2.7**	3	1.3 **3.9**	**29.8** *(28.9)*
34	-	-	2	0.59 **1.2**	-	-	6	**0.6**	-	-	-	-	18.8	**1.8**	-	-	**3.6** *(3.2)*
35	-	-	-	-	-	-	-	-	-	-	-	-	6	**0.6**	-	-	**0.6** *(0.5)*
36	-	-	-	-	-	-	-	-	-	-	100	**10.7**	9.4	**0.9**	4	1.3 **5.2**	**16.8** *(14.7)*
37	-	-	1	**0.59**	-	-	6	**0.6**	-	-	-	-	9.4	**0.9**	1	**1.3**	**3.4** *(3.2)*
38	-	-	-	-	-	-	6	**0.6**	-	-	-	-	-	-	-	-	**0.6** *(0.6)*
39	-	-	3	0.59 **1.8**	-	-	-	-	-	-	-	-	28.2	**2.7**	1	**1.3**	**5.8** *(5.2)*
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	3	**0.3**	-	-	-	-	-	-	-	-	**0.3** *(0.3)*
42	-	-	3	0.59 **1.8**	1	-	-	-	178.2	**5.2**	-	-	28.2	**2.7**	1	**1.3**	**11** *(9.9)*
43	-	-	-	-	-	-	-	-	-	-	300	**32.1**	-	-	2	1.3 **2.6**	**34.7** *(29)*
TOTAL		**33**	**11**		**154**		**100** *(91)*		**45** *(40)*		**154** *(126)*		**56** *(46)*		**96**		**649** *(596)*

Table 2. The total carbon footprint from tourist activities (kg of CO_2-eq.); aggregate data; estimates are by the **DEFRA** method.
Only carbon-producing tourist activities are analysed. The numbers in brackets indicate the 'direct' GHG emissions only.

№	Tourist activities: attractions	Carbon intensity	Tourist activities: entertainment	Carbon intensity-	Tourist activities: activities	Carbon intensity	Transport								Dining out	Carbon intensity	**Total GHG emissions**
							Bus		Coach		Car rental		Taxi				
							km	kg	km	kg	km	kg	km	kg			
1	1 1	1.51 1 **2.51**	-	-	-	-	62	**10**	-	-	-	-	-	-	2	1.3 **2.6**	**15.1** *(13.5)*
2	1 1	1.51 1 **2.51**	-	-	-	-	62	**10**	-	-	-	-	28.2	**2.3**	3	1.3 **3.9**	**18.7** *(16.8)*
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.3 **2.6**	**2.6** *(2.6)*
4	1	**1.51**	-	-	1	**18**	45	**7.2**	-	-	-	-	-	-	2	1.3 **2.6**	**29.3** *(28.2)*
5	1 1	1.51 1 **2.51**	-	-	1	**18**	-	-	-	-	202.3	**16.8**	28.2	**2.3**	3	1.3 **3.9**	**43.5** *(40.6)*
6	1	**1**	-	-	-	-	-	-	-	-	132.5	**11**	-	-	2	1.3 **2.6**	**14.6** *(12.9)*
7	1 1	1.51 1 **2.51**	-	-	-	-	111.5	**17.9**	-	-	-	-	-	-	2	1.3 **2.6**	**23** *(20.2)*
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1	**1**	-	-	1	-	26.4	**4.2**	854	**23.6**	-	-	18.8	**1.5**	2	1.3 **2.6**	**32.9** *(28.3)*
11	1	**1**	1	**0.59**	1	-	26.4	**4.2**	35.8	**1**			9.4	**0.8**	1	**1.3**	**8.9** *(8)*
12	-	-	1	**0.59**	-	-	-	-	-	-	-	-	12.4	**1**	-	-	**1.6** *(1.5)*
13	-	-	2	0.59 **1.2**	-	-	-	-	-	-	-	-	18.8	**1.5**	2	1.3 **2.6**	**5.3** *(5.1)*
14	-	-	-	-	-	-	9.4	**1.5**	-	-	-	-	-	-	1	**1.3**	**2.8** *(2.6)*
15	1 2	1.51 1 **3.51**	-	-	-	-	137.7	**22.2**	-	-	-	-	18.8	**1.5**	2	1.3 **2.6**	**29.8** *(26.1)*
16	-	-	2	0.59 **1.2**	-	-	-	-	-	-	-	-	18.8	**1.5**	-	-	**2.7** *(2.5)*
17	1	**1**	3	0.59 **1.8**	-	-	26.4	**4.2**	-	-	400	**33.2**	28.2	**2.3**	5	1.3 **6.5**	**49** *(42.9)*
18	1	**1**	-	-	1	-	81.7	**13.1**	460	**12.7**	-	-	18.8	**1.5**	2	1.3 **2.6**	**30.9** *(26.7)*
19	1	**1**	-	-	-	-	-	-	-	-	300	**24.9**	18.8	**1.5**	2	1.3 **2.6**	**30** *(26)*

20	-	-	-	-	1	**15.5**	6	**1**					28.2	**2.3**	2	1.3 **2.6**	**21.4** *(21)*
21	1	**1.51**	-	-	1 1	18 15.5 **33.5**	54.4	**8.8**	-	-	-	-	37.6	**3**	5	1.3 **6.5**	**53.3** *(51.6)*
22	1	**1.51**	-	-	-	-	35.6	**5.7**	-	-	-	-	-	-	-	-	**7.2** *(6.3)*
23	-	-	-	-	-	-	-	-	-	-	-	-	37.6	**3**	4	1.3 **5.2**	**8.2** *(7.9)*
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	1 1	1 1.51 **2.51**	-	-	-	-	62	**10**	-	-	-	-	9.4	**0.8**	-	-	**13.3** *(11.6)*
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	2	18 **38**	-	-	-	-	-	-	18.8	**1.5**	2	1.3 **2.6**	**40.1** *(40)*
28	1	**1**	-	-	1	**15.5**	32.4	**5.2**	-	-	-	-	18.8	**1.5**	3	1.3 **3.9**	**27.1** *(26.1)*
29	1 1	1 1.51 **2.51**	-	-	-	-	62.5	**10.5**	-	-	-	-	18.8	**1.5**	3	1.3 **3.9**	**18.4** *(16.6)*
30	1	**1**	-	-	-	-	26.4	**4.2**	-	-	-	-	18.8	**1.5**	3	1.3 **3.9**	**10.6** *(9.8)*
31	-	-	-	-	-	-	-	-	-	-	-	-	59.4	**4.8**	6	1.3 **7.8**	**12.6** *(12.1)*
32	-	-	-	-	1	-	32.8	**5.3**	-	-	-	-	-	-	1	**1.3**	**6.6** *(5.7)*
33	1	**1.51**	-	-	1	**18**	35.6	**5.7**	-	-	-	-	28.2	**2.3**	3	1.3 **3.9**	**31.4** *(30.2)*
34	-	-	2	0.59 **1.2**	-	-	6	**1**	-	-	-	-	18.8	**1.5**	-	-	**3.7** *(3.3)*
35	-	-	-	-	-	-	-	-	-	-	-	-	6	**0.5**	-	-	**0.5** *(0.4)*
36	-	-	-	-	-	-	-	-	-	-	100	**8.3**	9.4	**0.7**	4	1.3 **5.2**	**14.2** *(12.9)*
37	-	-	1	**0.59**	-	-	6	**1**	-	-	-	-	9.4	**0.7**	1	**1.3**	**3.6** *(3.4)*
38	-	-	-	-	-	-	6	**1**	-	-	-	-	-	-	-	-	**1** *(0.8)*
39	-	-	3	0.59 **1.8**	-	-	-	-	-	-	-	-	28.2	**2.3**	1	**1.3**	**5.4** *(5.1)*
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	3	**0.5**	-	-	-	-	-	-	-	-	**0.5** *(0.4)*
42	-	-	3	0.59 **1.8**	1	-	-	-	178.2	**4.9**	-	-	28.2	**2.3**	1	**1.3**	**10.3** *(9.2)*
43	-	-	-	-	-	-	-	-	-	-	300	**24.9**	-	-	2	1.3 **2.6**	**27.5** *(23.6)*
TOTAL		**33**	**11**		**154**		**154** *(130)*		**42** *(35)*		**119** *(100)*		**48** *(43)*		**96**		**657** *(602)*

Table 3. The total carbon footprint from tourist activities (kg of CO_2-eq.); aggregate data; estimates are by **Gössling *et al.* (2005)** method. *Only carbon-producing tourist activities are analysed.*

№	Tourist activities: attraction	Carbon intensity	Tourist activities: entertainment	Carbon intensity-	Tourist activities: activities	Carbon intensity	Transport								Dining out	Carbon intensity	Total GHG emissions
							Bus		Coach		Car rental		Taxi				
							km	kg	km	kg	km	kg	km	kg			
1	1 1	1.51 1 2.51	-	-	-	-	62	5.6	-	-	-	-	-	-	2	1.3 2.6	10.7
2	1 1	1.51 1 2.51	-	-	-	-	62	5.6	-	-	-	-	28.2	1.7	3	1.3 3.9	13.7
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.3 2.6	2.6
4	1	1.51	-	-	1	18	45	4.1	-	-	-	-	-	-	2	1.3 2.6	26.2
5	1 1	1.51 1 2.51	-	-	1	18	-	-	-	-	202.3	12.4	28.2	1.7	3	1.3 3.9	38.5
6	1	1	-	-	-	-	-	-	-	-	132.5	8.1	-	-	2	1.3 2.6	11.7
7	1 1	1.51 1 2.51	-	-	-	-	111.5	10.2	-	-	-	-	-	-	2	1.3 2.6	15.3
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1	1	-	-	1	-	26.4	2.4	854	18.6	-	-	18.8	1.1	2	1.3 2.6	25.7
11	1	1	1	0.59	1	-	26.4	2.4	35.8	0.8			9.4	0.6	1	1.3	6.7
12	-	-	1	0.59	-	-	-	-	-	-	-	-	12.4	0.7	-	-	1.3
13	-	-	2	0.59 1.2	-	-	-	-	-	-	-	-	18.8	1.1	2	1.3 2.6	4.9
14	-	-	-	-	-	-	9.4	0.9	-	-	-	-	-	-	1	1.3	2.2
15	1 2	1.51 1 3.51	-	-	-	-	137.7	12.6	-	-	-	-	18.8	1.1	2	1.3 2.6	19.8
16	-	-	2	0.59 1.2	-	-	-	-	-	-	-	-	18.8	1.1	-	-	2.3
17	1	1	3	0.59 1.8	-	-	26.4	2.4	-	-	400	24.4	28.2	1.7	5	1.3 6.5	37.8
18	1	1	-	-	1	-	81.7	7.4	460	10	-	-	18.8	1.1	2	1.3 2.6	22.1
19	1	1	-	-	-	-	-	-	-	-	300	18.3	18.8	1.1	2	1.3 2.6	23

20	-	-	-	-	1	**15.5**	6	**0.5**					28.2	**1.7**	2	1.3 **2.6**	**20.3**
21	1	**1.51**	-	-	1 1	18 15.5 **33.5**	54.4	**5**	-	-	-	-	37.6	**2.3**	5	1.3 **6.5**	**48.8**
22	1	**1.51**	-	-	-	-	35.6	**3.2**	-	-	-	-	-	-	-	-	**4.7**
23	-	-	-	-	-	-	-	-	-	-	-	-	37.6	**2.3**	4	1.3 **5.2**	**7.5**
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	1 1	1 1.51 **2.51**	-	-	-	-	62	**5.6**	-	-	-	-	9.4	**0.6**	-	-	**8.7**
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	2	18 **36**	-	-	-	-	-	-	18.8	**1.1**	2	1.3 **2.6**	**39.7**
28	1	**1**	-	-	1	**15.5**	32.4	**3**	-	-	-	-	18.8	**1.1**	3	1.3 **3.9**	**24.5**
29	1 1	1 1.51 **2.51**	-	-	-	-	62.5	**6**	-	-	-	-	18.8	**1.1**	3	1.3 **3.9**	**13.5**
30	1	**1**	-	-	-	-	26.4	**2.4**	-	-	-	-	18.8	**1.1**	3	1.3 **3.9**	**8.4**
31	-	-	-	-	-	-	-	-	-	-	-	-	59.4	**3.6**	6	1.3 **7.8**	**11.4**
32	-	-	-	-	1	-	32.8	**3**	-	-	-	-	-	-	1	**1.3**	**4.3**
33	1	**1.51**	-	-	1	**18**	35.6	**3.2**	-	-	-	-	28.2	**1.7**	3	1.3 **3.9**	**28.3**
34	-	-	2	0.59 **1.2**	-	-	6	**0.6**	-	-	-	-	18.8	**1.1**	-	-	**2.9**
35	-	-	-	-	-	-	-	-	-	-	-	-	6	**0.4**	-	-	**0.4**
36	-	-	-	-	-	-	-	-	-	-	100	**6.1**	9.4	**0.6**	4	1.3 **5.2**	**11.9**
37	-	-	1	**0.59**	-	-	6	**0.6**	-	-	-	-	9.4	**0.6**	1	**1.3**	**3.1**
38	-	-	-	-	-	-	6	**0.6**	-	-	-	-	-	-	-	-	**0.6**
39	-	-	3	0.59 **1.8**	-	-	-	-	-	-	-	-	28.2	**1.7**	1	**1.3**	**4.8**
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	3	**0.3**	-	-	-	-	-	-	-	-	**0.3**
42	-	-	3	0.59 **1.8**	1	-	-	-	178.2	**3.9**	-	-	28.2	**1.7**	1	**1.3**	**8.7**
43	-	-	-	-	-	-	-	-	-	-	300	**18.3**	-	-	2	1.3 **2.6**	**20.9**
TOTAL		**33**	**11**		**154**		**87**		**33**		**88**		**36**		**96**		**538**