Estimated Carbon Footprint of foreign tourists in Iceland – A bottom-up analysis of direct CO_2 emissions

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30 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Environmental and natural resources.

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Abstract

The tourism industry plays a major role in the Icelandic economy. Tourism can bring about economical prosperity and social wellbeing, but that contribution can often be at the expense of the natural environment – both on a local and global scale.
The focus of this research is a carbon footprint analysis of the tourism industry in Iceland. The aims are to cast light on this often forgotten part of the industry and thus, hopefully, contribute to the integral understanding of the environmental impact of tourists. From there, mitigation measures can be taken by relevant authorities, the companies involved, and the tourists themselves. The current literature on various carbon footprinting analyses was reviewed in order to investigate which method would be best suited for this type of research given the data available. With a bottom-up approach, three hypothetical scenarios were created: low, medium and high consumption behaviour, all derived from the results of an extensive survey conducted in the summer of 2011 for the Icelandic Tourism Board. The carbon footprint analysis focuses on direct emissions from three tourism sectors; transportation, accommodation and activities/attractions. Finally, recommendations for improvements include mandatory environmental management systems for all companies who are in the tourism industry and increased awareness and information provision to tourists.

Útdráttur

Ferðaþjónustan á Íslandi skiptir þjóðarbúskapinn miklu máli. Ferðaþjónusta getur borið í skauti sér efnahagslega og félagslega farsæld sem getur þó verið á kostnað hins náttúrulega umhverfis – bæði svæðisbundið sem og á heimsvísu. Meginrannsóknarspurningin er hvað áætlað kolefnisfótspor erlendra ferðamanna er innan þriggja tiltekinna geira ferðaþjónustunnar. Tilgangurinn er að varpa ljósi á þennan oft gleymda hluta ferðaþjónustunnar og í kjölfarið vonandi auka skilning á umhverfisáhrifum ferðamanna – svo hægt sé að beita mögulegum mildunaraðferðum af hluteigandi yfirvöldum, ferðaþjónustufyrirtækjunum og af ferðamönnunum sjálfum. Með því móti getur áframhaldandi vöxtur átt sér stað innan geirans í sátt við bæði menn og náttúru. Víðtæk yfirferð á gögnum og skrifum um kolefnisfótspor átti sér stað til að meta hvaða aðferð myndi henta best m.v. þau gögn sem lágu fyrir. Með neðansækinni aðferð, voru þrjár atburðarásir útbúnar; lág-, meðal- og há neysla – byggt á víðtækri spurningakönnun sem átti sér stað sumarið 2011 fyrir Ferðamálaráð Íslands. Kolefnisfótsporið byggir á beinum útblæstri frá þremur ferðaþjónustugeirum; fólksflutningum, gistingu og afþreyingu.
Uppástungur um bætta frammistöðu fela m.a. í sér að skylda innleiðingu á umhverfisstjórnunar-kerfum fyrir öll fyrirtæki í ferðaþjónustunni sem og að bæta upplýsingaflæði til ferðamanna.

Dedication

I would like to dedicate this work to my family – who are my inspiration and true motivator for responsible environmental behaviour.

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Abbreviations

CDM	Clean Development Mechanism of Kyoto Protocol
CF	Carbon Footprint
CO_2	Carbon dioxide
CO_{2-eq}	Carbon dioxide equivalent
GHG	Greenhouse Gas
gr	Metric gramme
HFO	Heavy Fuel Oil
ICAO	International Civil Aviation Organisation
IMO	International Maritime Organisation
ISK	Icelandic krona
ITB	Icelandic Tourist Board
kg	Kilogrammes
l	litre
MDG	Millennium Development Goals
Mpg	Miles per gallon
Nm	Nautical miles
t	Metric tonnes
Pax	Paying passenger
pkm	Passenger kilometres
ppm	Parts per million
TSA	Tourism Satellite Account
UN	United Nations
UNEP	United Nations Environmental Program
UNWTO	United Nations World Tourism Organisation

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Finally, and most importantly, I would like to thank my family for their tremendous support during the last few months.

1 Introduction

Ever since humans started to walk the Earth, they have constantly been exploring and mapping it. It is in the human nature to travel and the reasons and motivation behind it can be various and complex e.g. personal, educational or financial, to name but a few. Places that were once considered remote are now frequently visited, and it is probably safe to assume that very few places still remain completely unexplored and untouched by humanity.

The human population is also a contributing factor in relation to available space. In the beginning of the 1800s, the human population was estimated at around 1 billion inhabitants (USCB 2002), but currently 7.1 billion people roam the Earth (USCB 2013), with a peak estimated projection of 9.1 billion by 2050 (USCB 2002). During this process of growth man has certainly put its mark on Earth and will continue to do so. What once was a simple path for hunters through a rough terrain is now a multi-lane highway carrying thousands of consumers to their destinations at speeds never before seen. Man´s footprint on Earth is becoming more and more obvious. One by one, geographical hindrances have been conquered, thus making the world more accessible. In the name of progress, trade, time efficiency and globalization, advances in travel modes such as roads, railways, airways and the sea have all contributed further to this development and given humans an opportunity to travel rather effortlessly. In 2012 the tourism industry was believed to be a 1,075 billion dollar industry by the United Nations World Tourism Organisation (UNWTO 2013).

Needless to say, most modern transportation modes rely heavily on fossil fuel energy and the consumption behaviour of the traveller. Furthermore, travelling calls for added infrastructure which has also increased – not only in the form of highways, massive bridges, tunnels and ship-locks, but also in terms of service provision at airports, bus-stations, hotels, restaurants, fuelling stations, and many more.

Modern human consumption behaviour has also reached new heights. For instance, the amount spent on goods and services at the global household level, or private consumption expenditures, has quadrupled since 1960, reaching $20 trillion (adjusted to 1995 dollars) in 2000 (Worldwatch 2013). The pressure from increased consumption and population on the world ecosystem services is acknowledged by the United Nations Environmental Program (UNEP 2009) and expected to exacerbate the effects of climate change.

Pollution is also becoming a widespread problem. It is defined differently across the globe and therefore probably viewed differently. One of the definitions states that pollution is:

> Presence of matter (gas, liquid, solid) or energy (heat, noise, radiation) whose nature, location, or quantity directly or indirectly alters characteristics or processes of any part of the environment, and causes (or has potential to cause) damage to the condition, health, safety, or welfare of animals, humans, plants, or property.
>
> (TNAU 2013)

Pollution with regards to household waste accumulation, radioactive waste and water, are all stressing matters. However, atmospheric pollution must be one of the greatest challenges humans have faced so far; increasing emissions of greenhouse gases (GHG) which accumulate in the atmosphere and causes it to retain more heat. The *International Energy*

Agency (IEA 2013) estimates that in 2011 global anthropogenic CO_2 emissions due to fossil fuel combustion (coal/peat, oil, natural gas) were 31,342 million metric tonnes (t) opposed to 15,628 million t in 1973. CO_2 concentration has increased from 280 parts per million (ppm) since the industrial revolution began (De Bruijn 2012) up to 399 ppm (CO_2Now 2014), while 350 ppm is believed to be the threshold beyond which it is not possible to have a liveable planet (350.org 2013). Accumulated GHG eventually start to cause various meteorological alterations, i.e. on precipitation, temperature patterns and ocean salinity to name only a fraction of the possible effects of climate changes.

By no means have we reached the end of proven fossil fuel reserves in the world. Known resources are constantly graduating into the reserve category due to financial reasons and/or technological advancements. Current known reserves are expected to last for several decades; coal even for centuries (Sims et al 2007). Further exploitation of those resources will be at the expense of the environment and thus go against the sustainable development paradigm which is, according to the Brundtland report, when humans are able to meet their current needs in terms of natural resources without compromising future generations' opportunity to meet their own needs (UN 1987). In the sustainable development paradigm, the three guiding pillars – social, economical and environmental – should all be respected equally.

This study will focus on CO_2 emissions due to the behavioural choices made by foreign visitors in Iceland. Tourism behaviour and demand differs from the residents of their host nation, making it important to measure their activities separately (Whittlesea and Owen 2012). When the environmental impact of an anthropogenic action is evaluated in one way or another, it usually involves some kind of yardstick or a measurement tool – in this case, the carbon footprint analysis.

1.1 Footprint analysis

A major contribution has come from the global scientific community to the subject of climate change during the last couple of decades. In the process of that work, different scientists from interdisciplinary fields have created various measurements and definitions. The footprint analogy is one of the terms currently used and applies to a couple of methodologies to assess the anthropogenic impact on nature. The original terminology was introduced in 1996 by Wackernagel and Rees as the *Ecological Footprint* (Wiedmann 2009).

1.1.1 Ecological Footprint

The Ecological Footprint (EF) is a measurement of how sustainably the Earth's resources are used. It takes into account Earth's bioproductivity and compares it to human consumption. The results are usually given in global hectares (gha) or space equivalents as Gössling (2002) prefers. Global hectares indicate how much area is needed to sustainably provide land for a certain degree of demand. One part of the EF is accounting for the ecosystems capabilities to absorb or intake waste (GFN 2012). Waste in this sense can be from various anthropological sources – for example CO_2 emissions.
The Worldwatch Institute (2013) states that if the planet's biologically productive land resources would be divided between all humans, it would equate to 1.9 hectares per capita. So, a person with a calculated EF less than 1.9 gha would be considered to be within the sustainable boundaries. However, the calculated global range of actual ecological footprints

is between 0.47 to 9.7 hectares – making the average about 2.3 hectares (Worldwatch 2013). This creates an "overshoot" of ecological services as Wackernagel and Rees phrase it, which goes against all notions of sustainability. If current consumption rates and population growth continues, the world will need the equivalent of a little less than three Earths to support its inhabitants by 2050 (GFN 2013).

Ecological footprint assigns the responsibility to the consumer but not the producer (this is explained later). The EF methodology, as introduced by Wackernagel and Rees on a nationwide scale, does not incorporate the tourism industry, among other things, therefore leaving out an important contributing factor. It is possible to measure the environmental impact of tourism via the EF, but a carbon footprint analysis is assumed to be a better tool in this case due to its narrower focus on GHG.

1.1.2 Carbon footprint

From the idealogy of EF another research field has developed, the *Carbon Footprint* (CF). The idea of measuring GHG has existed for a few decades, but it is not until 2005 that these two words are found together in the scientific literature. Since then, the usage of the term has been steadily increasing (Wiedmann and Minx 2008). The CF offers a comprehensive and understandable method to measure GHG emissions since it puts a weight-number on the environmental burden human activities impose on the Earth´s climate. The Carbon Footprint calculation can be applied on a wide range of scales – from a single product up to a whole nation. It involves primarily identifying "emissions sources by collecting activity data for each source (e.g. electricity usage) and converting this activity data into emissions levels" (Chan 2009, p.15). The basic approach involves finding the CO_2 emission factor, e.g. indicated in gramme (gr) per kilometre, gr per litre fuel, etc - and multiplying that with the total fuel consumption or distance travelled (De Bruijn et al 2012).

Carbon footprint (CF) calculations have been used extensively in product evaluations while their application in services has been limited (Wiedmann and Minx 2008). A general note should be made that CF is a tool to indicate how GHG intensive an industry or sector is. Therefore, as a measurement tool, CF cannot be used as an impact model to predict a GHG increase in one sector due to an increase in another (Hoque et al 2010).

Furthermore, there is no concensus on how to measure CF and what it should encompass. There are generally two approaches concerning what a CF should encompass – either the six most malicious GHG´s or carbon dioxide alone (Wiedmann 2009 and Gössling 2013).

1.1.3 Focused terminology - Only CO_2

Carbon Footprint measurements have often been done in the form of GHG accounting (Perch-Nielsen et al 2010; Dwyer et al 2010), where the six gas-types defined in the *Kyoto Protocol* from 1998 are accounted for in the form of kilograms of CO_2 equivalent (kg CO_2-eq). They are sometimes referred to as the "basket of six" (Wood and Dey 2009) i.e. carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFC´s); perfluorocarbons (PFC´s); and sulphur hexafluoride (SF_6) (UN 1998).

CO_2 as a gas substance is estimated to have a life expectancy of 100 years in the atmosphere. CO_2-eq is when all the GHG´s have been weighted relative to carbon dioxide using its 100 year global warming potential, i.e. with assistance of the relative conversion factors for each type of gas (De Bruijn 2012).

CO_2-eq is the standard international unit of measurement (STF 2012) and used in most international agreements, such as the *United Nations Framework Convention on Climate Change* (UNFCCC) and Kyoto Protocol who will both be explained later.
However the “basket of six” approach is sometimes applied flexibly since some researchers intentionally leave out some GHG and account for others, i.e. Hertwich and Peters (2009). Wiedmann and Minx (2008) argued that if researchers chose to account for all GHG, they should calculate them based on their respective emissions factors and that approach could be termed “climate footprint” (p.5). They consider it important that a mass unit of measurement is used where both direct and indirect CO_2 emissions are included. For the sake of clarity and practicality, only CO_2 emissions should be counted for while all other greenhouse gases should be left out.
Wiedmann´s and Minx´s (2008, p.4) definition of the Carbon Footprint is therefore:

> The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product.

This definition has not been free from criticism in the academic field. Some say that this approach leaves out almost one-quarter of GHG´s (Wright et al 2011).
Nevertheless, the CF definition introduced by Wiedmann and Minx (2008) is the definition this research follows since it is both clear and fits the purpose of this report; i.e. to estimate the carbon dioxide emissions of tourist behaviour. This method has also been applied on several previous occasions (e.g. Becken and Patterson 2006; De Bruijn et al 2012) and is considered to be a sound way of calculating the environmental impact of the tourism industry (De Bruijn et al 2012).

1.2 Motivation and objectives

Tourism is one of the fastest growing industries in the world with about 1,035 million arrivals in 2012 (UNWTO 2013). Iceland has certainly experienced burgeoning demand, receiving an increasing number of visitors during the last decade or so (Icestats 2013). The country appears to be popular and new records in tourism arrivals are broken annually (ITB 2014). But does tourism really have an environmental consequence and if so, in what sense? This could be a very important consideration for many nations reliant on tourism. Have there been any studies done on this matter? Does the simple act of modern travel harm the environment and is it possible that tourist behaviour is adding to the global concentration of anthropogenic CO_2 emissions?

A baseline must be found in order to evaluate the situation in the future. A reduced carbon footprint can certainly contribute to a better environment and further enhance the notion of a prosperous and sustainable tourism industry.

The general objectives of this study are:

- To estimate the carbon footprint of the average foreign tourist in Iceland, measured in kilograms of CO_2 per person, per day.

- To identify the most significant hotspots in that analysis i.e. the main contributing factors.

Furthermore:

- To explain what can be done in terms of mitigation methods to reduce the negative impact.

The answers to these questions will make an important contribution to an escalating discussion which has taken place in Iceland during recent years on various tourism impacts.

1.3 Contribution

A carbon footprint evaluation of the tourism industry has never been done in Iceland before (Welling 2013) – despite its usefulness to the industry and decision makers within that field. Therefore, the research could make a valuable contribution to the academic field which researches the environmental effects of tourism in Iceland.

The results can possibly add to the discussion of Iceland´s carrying capacity in the light of a rapid increase in tourist arrivals and various permutations regarding the revenue generated by imminent access fees and nature passes. For example, will the price of damaging carbon emissions be included in the fees/passes, or will the revenue simply be a tool to generate income (possibly used to maintain the sites and therefore maintain, hopefully, a positive tourism experience)? The CF might also contribute to the creation of a holistic view of the many environmental impacts that tourists can impose on Iceland. Many tourism operators often portray Iceland as pure and unspoilt (e.g. Icelandguest.com, Eagleair.com), which they still can reasonably assert for many areas, but the threat in specific locations is both imminent and real. The tourism industry has been and will continue to be both a victim and an offender when it comes to environmental impact. A carbon footprint estimate could therefore be used as a benchmark or reference point in that discussion.

When a carbon footprint has been understood and quantified, goals can be set and steps towards reductions can be assimilated and implemented. Therefore, this study might help local tourism businesses to understand the damaging effects of GHG emissions from tourism behaviour, especially CO_2. It will hopefully encourage them to set reduction goals for themselves and thoroughly monitor their emissions through a wide range of toolsets available within the field of environmental management systems e.g. ISO14001, Swan-label, green (also environmental) accounting, and many more.

A CF measurement could also give tourists an opportunity to compare the emissions impact that they would have at specific sites, and can provide the tourist with sufficient data to make a reasoned choice based on their individual impact preferences. A few countries have shown an interest in becoming carbon neutral destinations, e.g. New Zealand, the Maldives and Norway, but in many cases their steps towards this goal seem to lack true dedication (Gössling and Schumacher 2010). Therefore, environmental responsibility could benefit destinations in terms of competitiveness.

During the last two decades a large awakening has occurred among consumers regarding the environment, creating the green consumer and stimulating pressure on businesses to embrace a more sustainable pathway (Hoffman 2000, Wood and Dey 2009). Those businesses or individuals who are responsible and genuinely show the environment respect often reap certain social, economical and environmental benefits. Those businesses who follow closely their GHG emissions and make genuine attempts to deliver reductions, create a hallmark that often puts them one step ahead of their competitors (Niras 2011), so it can certainly be a deal-breaker. The selection of destination places for tourists is vast, which makes it even more important for a place to distinguish itself. Perhaps the future of that distinguishing process involves CO_2 calculations and mitigation? The justification can be at least twofold. Firstly, because host nations must understand the possible environmental impact that follows increased tourism and prepare for it, either via mitigation or adaption. Secondly, because the rising increase of environmental awareness that has been taking place in the world has spawned a growing group of green customers, those who go about their way to purchase environmentally friendly products, irrespective of the cost (Hoffman 2000; Wood and Dey 2009). With the focus on the green consumer – and possibly those who are on the verge of becoming green-consumers – a carbon footprint estimate can be an eye-opener for tourists on how their activities impact on the environment. It could possibly encourage them to be more aware of their behaviour and make them contemplate how best to reduce their emissions. Alternatively, they might simply chose a destination where they reduce their emissions during their stay as an indirect result of the carbon intensity of the local infrastructure, e.g. via electricity consumption generated from renewable energy sources.

1.4 Structure of the thesis

After introducing the footprint terminology and the thesis´ objective in this chapter, the second chapter will discuss the tourism impact. There, the stage is set and core issues identified that need to be dealt with i.e. the damaging effects of GHG emissions on both a local and global scale. To put things into perspective, an evaluation of Iceland´s overall CO_2 emissions is introduced.

Responses from various stakeholders in the tourism industry and international community are revealed. The contributions from the scientific community to understand, measure and explain these effects, is also discussed to formulate an overall view.

In chapter three the appropriate material used during the carrying out of this research is explained and previous studies on CO_2 emissions from tourism related industries are addressed. The main scientific contributions are drawn out to be used later. The research boundaries are depicted and the data acquisition is explained along with the scope of the research.

In chapter four, the methodology of this research is described, a picture of the three tourist types analysed is established, and a description given of how the results will be retrieved from three tourism-industry segments: transportation, accommodation and activities/attraction sites. Furthermore, the emissions factors relevant to each sector are introduced and their individual applications explained.

In chapter five the emission factors are applied to individual tourist behaviour and carbon footprint results are introduced. General discussions about the results take place simultaneously.

Finally, in chapter six the conclusions are combined and a comprehensive overview given while the research questions are answered.

Next, a brief summary of the issues discussed in this first chapter.

1.5 Summary

In the first chapter it has been discussed that humans are having a dramatic effect on Earth through increased consumer demand, particularly for fossil fuels as a means of energy generation. As a consequence, pollution is becoming a global problem. Despite the known detrimental effects, this process doesn´t seem to be ending anytime in the next few decades. Effects need to be measured and the ideology of the ecological footprint (EF) was introduced to reflect human demands on Earth's resources relative to sustainable limits. From the EF, the carbon footprint (CF) is derived, but it has a narrower focus – in some cases it is a measure of six different greenhouse gases (CO_2-eq); this study will only measure the CO_2 emissions.

The tourism industry, which is Iceland´s fastest growing industry, is a contributing factor to the growth of its economy. The motivation and objective of this study is to estimate the carbon footprint of international tourists who visit Iceland, and in so doing cast light on their environmental consequences, particularly bearing global warming in mind. The results will set a baseline which will benefit decision makers at both ends, i.e. on how to possibly mitigate their emissions. At the end of chapter one, the structure of this thesis was outlined.

In the next chapter the impact of tourism will be further elaborated.

2 Tourism impact and measurements

The following chapter is primarily intended to cast light on the tourism industry and briefly explain both its positive and possible negative impacts. The tourism industry, as well as the whole world, faces the threat of climate change and Iceland is no exception.
But before we continue any further, it is perhaps appropriate to define the concept of tourism.

2.1 Tourism

According to the United Nations World Tourism Organisation (UNWTO), tourism is:

> […] a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes. These people are called visitors (which may be either tourists or excursionists; residents or non-residents) and tourism has to do with their activities, some of which imply tourism expenditure.
>
> (UNWTO 2012b)

Furthermore,

> It comprises the activities of persons traveling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited.
>
> (Eurostat, OECD, UN, UNWTO 2001)

Tourism is usually considered to be a benefit for receiving nations in monetary terms but also in a social manner where it can encourage peace and cultural tolerance (Ban Ki-moon 2007). During the past six decades, the tourism industry has grown enormously, from 25 million international arrivals in 1950 to 1.09 billion in 2013 (UNWTO 2014). Tourism is expected to grow by 3.3% annually until reaching 1.8 billion international arrivals by 2030. The industry is estimated to be responsible for 1 of every 11 jobs in the world, 9% of Gross Domestic Product (GDP) (direct, indirect and induced impact) and 6% of world´s exports (UNWTO 2013).

In terms of pollution, tourism is estimated to be responsible for 5% of global CO_2 emissions, where 4% is estimated to come from transportation and 1% from the accommodation sector, while other tourism activities account for less than 1% (UNWTO 2011). UNWTO expects that between 2005 and 2035 CO_2 emissions from the industry will increase by 152% (Simpson et al 2008). The tourism industry has sometimes been depicted as the major cause of increased pollution at local destinations relative to their carrying capacity (UNEP 2003a). In relation to the definition of pollution, as seen in the previous chapter, one can easily argue that tourists (and their quantity) are a combination of matter and energy that affect their visited environment - if the sustainable paradigm is not involved.

Pollution from tourism can be from various sources, from noise-disturbances and visual pollution to chemical pollution – including sewage release, solid waste and, last but not least, air emissions (UNEP 2003a). Richard Butler (1980) realised this multiple threat from tourism and issued a model/curve where the concept of carrying capacity was adressed for tourist destination places. At first, places tend to be in the position of being only visited rarely by explorers. Then places experience development during an unspecified timeframe until they either reach a plataeu or stagnate. The conditions at the destination place (e.g. nature, infrastructure, social attitude and economics) are important when predicting which way a destination place will go. The actions of local authorities and tourism companies are very important during a stagnation-period as they can either cause further rejuvenation or decline of the destination place. With this in mind, Iceland must tread carefully because signs of over-exploitation are already visible (explained fully later).

Undeniably, the interaction between man and nature through tourism can have negative impacts on nature, for instance through the construction of general infrastructure needed to service tourists, e.g. hotels, amusements parks etc, at the cost of space equivalents. Critical resources are also important, for instance water and energy supplies. If a sustainable vision is not upheld, then these valuable environmental resources that the whole community relies on are put at risk (UNEP 2003b).

However, despite the environmental focus of this thesis, it is simply unfair to compare tourism directly to pollution. The UNWTO for example "promotes tourism as a driver of economic growth, inclusive development and environmental sustainability" (UNWTO 2013). For many developing nations tourism is believed to be a major contributing factor in achieving the UN´s ambitious eight *Millennium Development Goals* (MDG), especially eradicating poverty (#1), increasing gender equality (#3) and reaching environmental sustainability (#7). It is also believed to assist in building global partnerships (#8) for future developments. Tourism is believed to have less effect on achieving universal primary education (#2), reducing child mortality (#4), improving maternal health (#5), and combating HIV/AIDS, malaria and other diseases (#6) (UNWTO 2012a). Nonetheless, financial benefits often following increased tourism can certainly assist in achieving many of the goals relating to healthcare and education. Furthermore, improvement of socio-economic growth through tourism in an environmentally sustainable manner seems to be UNWTO´s main priority. This is particularly done through education, exchange of information and highlighting of statistics (UNWTO 2013).

However, there is a continual threat to tourism due to a changing climate, demanding appropriate responses from involved parties.

2.2 Reactions to Climate Changes

A limit has been set for global warming, a threshold at 2°C global average temperature increase – if the temperature rises more than that, environmental changes will become more dramatic throughout the globe. Regretably, the limit of 2°C is dangerously close (Rockström et al 2009) and drastic measures involving both mitigation and adaptation actions seem to be inevitable. Adaptation to a changing climate can involve both hard (technical) and soft (non-technical) measures to influence socio-economic behaviour towards climate adaptation (FCCC 2009). Perhaps the Icelandic Nature Pass would be ideal in this matter, giving the issue a financial weight and including the price of carbon emissions?

In the light of detrimental effects of releasing stored carbon and other GHG into the atmosphere, many concerned nations decided to join forces and seek a resolution together. In 1979, the *Convention on Long-range Transboundary Air Pollution* (CLRTAP) was held in Geneva. There, the first international and legally binding agreement to combat air pollution was signed (UNECE n.d.). However, the root of today´s climate change negotiations can be traced to the Earth Summit in Rio de Janeiro in 1992 when the *United Nations Framework Convention on Climate Change*, (UNFCCC) was signed –

a non-binding contract made as an attempt to stabilize and reduce the pollutant concentration in the atmosphere. This agreement is often referred to as simply the Rio-Declaration and is considered to have been a true milestone in an ongoing battle against GHG (UNFCCC 2013).

In 1995, under the UNFCCC framework, the first meeting of the *Conference of Parties* (COP) was held in Berlin. There, emissions from bunker fuels were discussed. Bunker fuels are used for international aviation and maritime transportation and it was requested that their emissions were to be further controlled and allocated (UNFCCC 2014).

In 1997 the Kyoto Protocol was adopted by the member countries of the UNFCCC and signed in 1998 by 184 member countries (UNFCC 2006). The Kyoto Protocol was a binding agreement among signatory nations to co-ordinate their measures for mitigation and adaptation to climate change, and it came into force in February 2005. Relevant nations commited to lower their GHG emissions down to 5.2% below 1990 levels during the first commitment period from 2008 to 2012. The second commitment period is valid until 2020 where the goal has been raised up to an 18% reduction compared to 1990 levels (UNFCCC 2013). However, the Kyoto Protocol did not address bunker fuels, which certainly is an important emission factor within the transportation industry. Bunker fuels are mentioned in the agreement but their emissions shall be separately monitored and reduced within the *International Civil Aviation Organisation* (ICAO) and the *International Maritime Organisation* (IMO) framework. Both organisations must have environmental protection in mind and promote activities to address global climate change (UNFCCC 2014). Nevertheless, since the beginning of 2012 the European Union (EU) has incorporated emissions from aviation into its *Emissions Trading Scheme* (ETS). The ETS is a “cap and trade” system where the overall GHG emissions from the EU economy are limited. Industries get a quota which they can both sell and purchase from others, depending on their need. Flights to and from non-European countries are, however, still exempted (European Commission 2014).

Since 2009 the *International Air Transport Association* (IATA) has commited itself to reduce carbon emissions from aviation with 1.5% annual improvements in fuel efficiency until 2020. IATA has also set a goal to cap net emissions from 2020 and aims for carbon-neutral growth from there on until net emissions will be cut in half by 2050, compared to 2005 emissions (IATA 2013).

In terms of maritime vessels, the *International Convention for the Prevention of Pollution from Ships* (MARPOL) was adopted in 1973. It went through several adjustments within the *Marine Environment Protection Committee* (MEPC), but following the inclusion of Annex VI; Regulations for the Prevention of Air Pollution from Ships, in 1997 and enforced in 2005, an important step was taken in battling GHG at sea, mostly through the emissions derived from the sulphur content of ship fuel oil. In Annex VI deliberate emissions of all ozone depleting substances were prohibited and general limits set on sulphur oxide (SOx) and nitrogen oxide (NOx), ozone depleting substances (ODS) and volatile organic compound (VOC) emissions from ships. It was ratified by 53 countries, encompassing 82% of the gross tonnage of the world's merchant shipping fleet. The MEPC has acknowleged the responsibility of shipping transportation in the global context of GHG emissions, despite it´s relatively “environmentally friendly and fuel-efficient mode of transport” (IMO 2014a, p.2). The latest changes to MARPOL Annex VI were made in 2008 and enforced in 2010 when ambitious reduction goals were set. A sulphur cap applicable on a global scale was set at 3.5% m/m (as ratio of substance in total weight of solution) and intended to gradually decrease, reaching 0.50% m/m in 2020. The regulations are even stricter within so called *Sulphur Emission Control Areas* (SECA) – i.e. North Sea, Baltic Sea and off California

Coast – where the maximum allowed is currently 1% (from 2010), but will be reduced to 0.10% m/m from 2020 (IMO 2014b).
The IMO monitors and controls all GHG as defined in the Kyoto Protocol, and in specific relation to CO_2 it has estimated that international shipping was responsible for 2.7% of the global emissions in 2007. It has adopted mandatory measures to reduce all GHG from international shipping (IMO 2014c).

Next the effects of climate change on the tourism industry will be briefly examined.

2.2.1 Tourism and climate changes

The impacts of tourism are multiple and many different stakeholders are involved, both directly and indirectly. First and foremost, tourism relies heavily on various transportation modes and the workforce behind the tourism experience. Tourism has been acknowledged as an energy intensive industry, not only in the process of producing the tourism experience and relevant goods needed, but also for the supportive infrastructure required (Kelly and Williams 2007).

In 2003 the world witnessed its first *International Conference on Climate Change and Tourism*, held in Djerba, Tunisia. It was held in co-operation with the UNWTO, *United Nations Environmental Programme* (UNEP) and *World Meteorological Organisation* (WMO). There, for the first time, the two-way relationship between tourism and climate change was acknowledged (UNWTO 2011; Dwyer et al 2010).

At the second conference on this matter in Davos, Switzerland (2007), the vulnerability of tourism industries to any changes in the climate was further stressed since many economies rely heavily on tourism (UNWTO-UNEP-WMO 2008). The Davos Declaration´s aim was to ensure the sustainability of destination places and reduce the carbon footprint of the entire industry. Tourism industries were encouraged to make a plan that would describe their path towards a carbon-neutral environment and commited themselves to mitigated responses as a reaction to the threat of climate change (UNWTO 2011, UNWTO-UNEP-WMO 2008). It was concluded that tourism development, management and monitoring needs a holistic approach. Responsible behaviour in terms of climate change lies largely with the tourist itself but also the local government and individual tourism industries must react to this pressing matter – both national and local policies are needed with sustainability notions as a guiding light (UNEP and UNWTO 2005).
The sustainable tourism must evolve and mirror the "quadruple bottom line", where climate responsiveness is added to the conventional environmental, social and economic factors that are usually considered. The measures involved mitigation in transportation and the accommodation sector; adaptation to inevitable changes in climate; applying best available techniques where possible, i.e. adopting energy-efficiency and renewable energy sources; increasing education among stakeholders; and making sure financial resources were available to aid poorer countries (UNWTO-UNEP-WMO 2008).

At the sixteenth COP provided by the UNFCCC in Cancún in 2010, local governments were for the first time recognized as key governmental stakeholders in climate change efforts (ICLEI 2010a).

However, climate change will not have the same outcome everywhere and the effects will definitely not be experienced in the same way. For example, many nations in the northern hemisphere could be blinded by possible new business opportunities e.g. in the agricultural sector, but that would be largely built on a short-term view because usually there is some sort of sacrifice involved (e.g. species migration/extinction). Iceland, the country of fire (heat) and ice, will experience increasing temperatures, and before long it will have more heat than ice (Jónsdóttir 2012). Therefore, it is quite possible that conditions for tourism in Iceland will change.

2.3 Distant Iceland

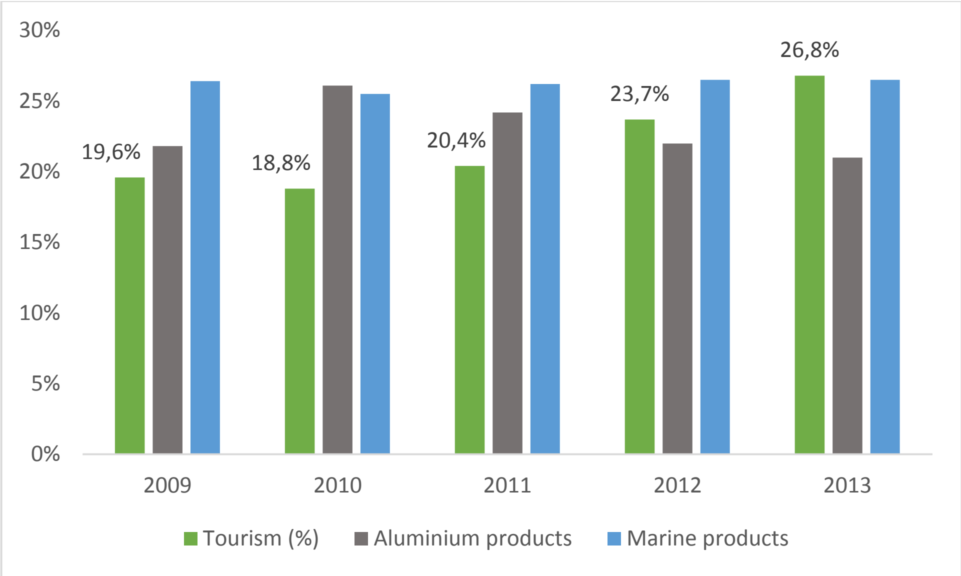
In 1950 it is estimated that 4,383 guests came to Iceland, but from 1960 to 1970 Iceland experienced its largest growth-period in tourism over a single decade, or 313% when 52,908 guests arrived in 1970 (Icestats 2004). In 2000 tourism arrivals had reached 302,900 but as shown in Table 2.1, tourism arrivals have continued to increase. Over the last three years Iceland has not experienced as dramatic increases as seen in the 1960s, but increases nevertheless, or up to 20% per year. Total tourism arrivals, including ferry/cruise ship passengers, counted 807,349 in 2013 and the average annual increase since 2000 has been 8.3% (ITB 2014).

Table 2.1 Tourists to Iceland through airports and seaports, 2009-2012

Year	2009	2010	2011	2012	2013
Guests	493,941	489,622	565,611	672,772	807,349
Change between years	-	-0,9%	+15.5%	+19%	+20%

Source: ITB 2014

The peak tourist season in Iceland is during the summer months, from June to August (ITB 2014), so it is probably safe to say that this island of roughly 103,000 km^2 becomes quite densely populated during those months, since the Icelandic population is only 320,000 people (Icestats 2014a).
Several sites in Icelandic nature are believed to have surpassed or are close to surpassing their carrying capacity since marks of deterioration are already visible – e.g. Friðland að Fjallabaki, Gullfoss, Geysir and Helgustaðanáma (Ólafsdóttir 2012; UST 2014). Much discussion and deliberation has taken place during the last few years on whether tourist taxes or entrance fees should be collected for Iceland´s most popular destination sites/magnets, where the expected revenue is supposed to be used to further build up the infrastructure and manage delicate areas (ITB 2013). Consequently, there has also been a heated discussion on how that fee should be collected and several suggestion have been mentioned, i.e. parking fees, Nature Pass, overall tourist tax, individual entrance fees and electronic travelpasses (Gekon 2013), to name only some of the possible options.



Source: Icestats 2014b

Figure 2.1 Proportion of total export value of products and services from Iceland 2009-2013 divided between industries

Foreign tourists in Iceland are important to the country´s economy and a valuable source of foreign currency as shown on Figure 2.1 where three of Iceland´s largest industries export value are depicted. In 2009 the tourism industry generated 155,522 million ISK worth of foreign currency, which was 19.6% of the total export value of products and services from Iceland that year. Apart from 2009 and 2010, where the tourism industry suffered from a minor setback, the industry has gradually increased its share of the total value of products and services exported from Iceland. In 2012 its share was 23.7%, producing 239,427 million ISK worth of foreign currency, and in 2013 it was responsible for 26.8%, generating 274,819 million ISK (Icestats 2014b). Now, if the number from 2013 is projected on to the Euro (€), which was valued at 158.5 ISK on December 31st 2013 according to the Central Bank of Iceland (2014), 274,819 million ISK equals to little more than €1.7 billion. The export value of other major industries has decreased at the same time. In the case of aluminium products it went from 26% to 21% between 2010 and 2013, while marine products (e.g. various fish products) stayed relatively stable at around 26% (Icestats 2014b), which vividly shows the growing importance of the tourism industry within the overall economy.

Icelandic tourism industry relies heavily on Scandinavian, English and European markets, since these markets accounted for 63% of all departures (nationalities of passangers are gathered when they leave Iceland) from Keflavik airport in 2011 and 2012 and 60% in 2013. North-American markets are also important since they accounted for another 17%. The majority of all inbound tourists arrive by air, or approximately 96% in 2011 and 2012 and 97% in 2013 (ITB 2014).

Table 2.2 Economic benefit of tourism for Iceland

Year	GDP (million ISK)	International tourist arrivals*	Domestic international tourism consumption (million ISK)	Consumption per tourist (ISK)	Tourism industry as proportion of GDP
2011	1,628,320	565,611	145,000	256,360	+ 6% (est)
2012	1,699,401	672,772	178,000	264,880	7.3% (est)
2013	1,786,244	807,349	211,000	270,160	7.7% (est)

* Through Keflavik International Airport +ferry/cruise ship passengers.

Source: Gekon 2013, ITB 2014, OECD n.d.

In Table 2.2 the economic benefit of tourism for Iceland is further depicted. In 2011 the tourism industry is estimated to be responsible for 6% of the country´s GDP, which was 1.6 billion ISK. The domestic consumption of international tourists was 145,000 million ISK and the consumption per tourist was 256,360 ISK. In the following years it increased steadily. In 2013 the domestic consumption of international tourists reached 211,000 million ISK and consumption per tourist was 270,160 ISK. In 2013 the tourism industry is estimated to be responsible for 7.7% of the country´s GDP (Gekon 2013, ITB 2014, OECD n.d.). Thus, for a rather small economy like Iceland, the economic benefit of tourism should be undisputed especially in light of the fact that among UNWTO member countries the GDP on a global scale is 9% (UNWTO 2013).

Nonetheless, monetary benefits alone should not blind the host nation. The destination place needs to be maintained since the tourism destination is only as good as the experience tourists get during their stay and therefore many things to attend to. In relation to that, it is perhaps appropriate to analyse Iceland's overall carbon footprint in order to put things into perspective, before the focus of attention is fixed on the tourists themselves.

2.3.1 Carbon Footprint of Iceland

When Hertwich and Peters (2009) calculated the CF per capita (CO_2-eq) of 73 nations through global trade-linked analysis, they found out that the average per capita footprint varies from 1 t of CO_2-eq per year (CO_2-eq/y), e.g. an African country, to +30 t CO_2-eq/y, e.g. Luxembourg. They concluded that CF per capita increases in correlation with the size of an economy.

Unfortunately, Iceland was not included in their calculations, which referred to emissions in 2001. Nonetheless, if the total GHG number for Iceland in 2001, or 3,814,000 t (Icestats 2012) is divided by its population, i.e. 286.575 people (Icestats 2014), we get 13.3 t CO_2-eq/y per person, putting Iceland's emissions per capita close to the average citizens of Greece (13.7 t CO_2-eq/y) and France (13.1 t CO_2-eq/y) (Hertwich and Peters 2009).

The total GHG emissions in Iceland for 2010 and 2011 were 4,618,000 and 4,413,000 t CO_2-eq, respectively (EAI 2013). However, CO_2-eq (GHG) will not be used as the measuring stick during this research. Therefore, if the CO_2 emissions for the whole year 2011 (simply chosen here because it is the main reference year for this research) is divided between the population registered for January 1st 2012, or 319,575 inhabitants (Icestats 2014a), the result is 10.7 t CO_2 per capita.

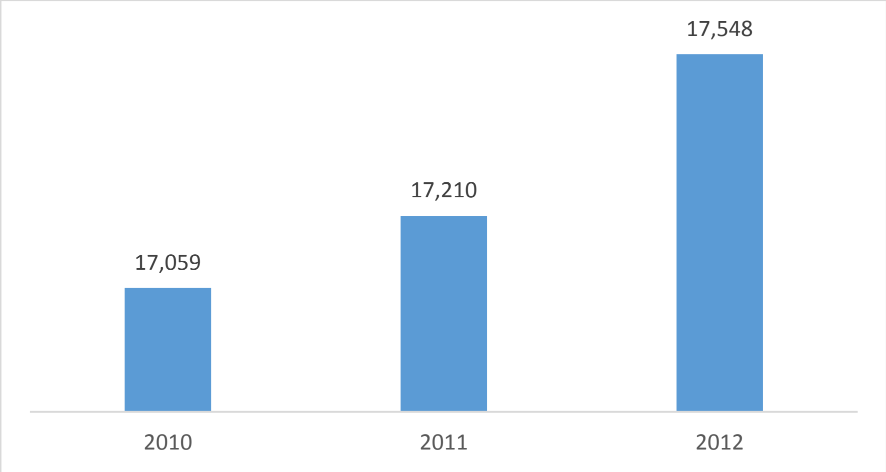
In Table 2.3 the total CO_2 emissions (from various industry sectors) in Iceland during 2009-2011 can be viewed. The largest contributors are various industrial processes with 1,610,000 t in 2011, though the emissions are fairly constant from 2009. Road vehicles are the second largest contributor with 788,000 t but have been slowly reducing between the years. It is quite positive to see that the emissions from fishing, stationary combustion, construction and other reduced between the years. Geothermal is the only sector that increased from 2009, but it is still lower than 2010 levels.

Table 2.3 CO_2 emissions (t) in Iceland: 2009-2011

Industries	2009	2010	2011
Fishing	597,000	535,000	500,000
Road vehicles	852,000	806,000	788,000
Stationary combustion, liquid fuels	112,000	97,000	89,000
Industrial processes	1,609,000	1,616,000	1,610,000
Construction	129,000	102,000	88,000
Geothermal	168,000	189,000	179,000
Other	104,000	88,000	80,000
Total CO_2 emission (t)	3,572,000	3,432,000	3,333,000

Source: EAI 2013

Electricity is an important factor. Electricity in Iceland is mainly produced via hydropower (73%) and geothermal (27%) (National Energy Authority 2012), but electrodes in the power system grid are not marked with their origin of production. There are mainly five whole-sale producers who generate electricity into the distribution grid, i.e. Icelandic National Power (73%), Reykjavik Energy (17%), HS Energy (8%), Rarik (1.54%) and Westfjord Power Company (0.45%) (Íslandsbanki 2012). According to the largest producer, Icelandic National Power (2011), the environmental cost of producing one gigawatthour (GWh) of electricity is 3,217 t CO_2-eq for geothermal and 1,104 t CO_2-eq from hydropower resources. Icelandic National Power provides its GHG emissions mostly in CO_2 equivalents, but their emissions are thoroughly broken down in the appendix of their annual reports.



Source: National Energy Authority 2013

Figure 2.2 Total Electricity Production in Iceland – GWh

Iceland is certainly fortunate to have plenty of natural resources in terms of electricity production, leaving the nation nearly independent from the combustion of liquid fuels for energy. Renewable electricity production has increased (see Figure 2.2) from 2010 to 2012 by about 0.5 GWh, making a total of 17.5 GWh for 2012. This makes the country appealing to energy demanding companies, i.e. to purchase green energy as an attempt to lower their total GHG emissions from their production.

As previously stated, the tourism industry is the fastest growing industry in Iceland. Tourism is also an energy demanding industry and for Iceland, as an island in the middle of the Atlantic Ocean, it is highly dependent on various infrastructures (e.g. vehicles and roads) and the import of goods (e.g. food and fuel) in order to be able to facilitate a satisfactory service and tourism experience. Therefore, despite the fact that there is 'no smoke coming from an obvious chimney', it is a polluting industry which needs to be taken seriously by being measured, monitored and controlled. It is also an industry with full capability of becoming a thriving green industry, and Iceland's renewable energy can play a central role.

Later in this study an attempt will be made to give the production process of an average Icelandic kilowatt-hour (kWh) a CO_2 weight, which will be important when the emissions deriving from the energy demand of tourists is estimated.

2.4 Summary

In chapter two it has been established that tourism is a very large industry throughout the world, providing 1 out of every 11 jobs and with expected average growth in visitor numbers of 3.3% on annual basis until 2030. The tourism industry can certainly bring about many positive results in a social, economic and environmental context, but there are also negative impacts to be aware of, e.g. pollution in its many forms.
Global warming creates a global threat to tourism and the global communities' efforts to address this problem through various contracts and protocols has been a good first step – the most important steps most likely being the Rio-Declaration (1992) and the Kyoto-Protocol (2005). The tourism industry realises this threat and has joined forces in an effort to battle this detrimental situation, e.g. with the International Conference on Climate Changes and Tourism (2003), and via the increased promotion of the sustainable tourism vision. Tourism is important for the Icelandic economy and has been steadily growing during the

last couple of decades. In 2013 the tourism industry experienced 807,349 visitors and was responsible for 26.8% of the total export value of products and services from Iceland. In 2011 each tourist spent approximately 256,360 ISK during their stay here, but in 2013 that number had risen to 270.160 ISK. Nonetheless, so many visitors can create pressure on the environment and the country´s inhabitants, especially when the quantity of visitors surpasses the numbers of inhabitants. An economy that relies heavily on tourism requires the natural environment to be maintained and respected. The local tourism industry should therefore aim to become sustainable in order to be viable while at the same time protecting natural assets. A rough carbon footprint analysis of Iceland was provided, i.e. 10.7 t per person in 2011. Iceland´s green electricity production gives it an advantage in comparison to many other tourist destinations.

In the next chapter the appropriate material used in this research will be thoroughly described.

3 Material

Tourism impact studies have been adjusting their focus from the conventional social and economical aspects to include more of the environmental aspect. As a result, the application of the CF approach and numbers of CF studies have increased in the last few years (Wiedmann and Minx 2008).
Generally, there are two different ways of assigning responsibility for GHG emissions; those are either production based or consumption based views (Peters and Hertwick 2006), sometimes also called expenditure based (Dwyer et al 2010). There are also two main methods of calculation: bottom-up and top-down. These different views and approaches will be briefly described in the following background section.

3.1 Background

The following sets of text are short descriptions of previous studies and definitions applicable to the CF literature which are important to gain a coherent perspective of the analytical approach described in chapter four.

3.1.1 Consumption or Production based view

The conventional production based view of GHG accounting involves analyzing the GHG´s emissions from local production processes, but does not incorporate where their product is consumed, thus making the producer responsible. When applied to the national level, this approach takes into account all GHG producing units within a nation´s economy that contribute to its GDP (Larsen and Hertwich 2009). National emissions are usually calculated this way since the *Guidelines for National Greenhouse Inventories* (IPCC 2006) are production focused (Wu 2011).

The consumption based view of GHG accounting makes the final consumer responsible, since he is considered to be the main driver behind the demand (Wood and Dey 2009). All upstream GHG emissions are therefore allocated to him. Locally produced but exported goods are excluded and accounted for in the area where they are consumed (Larsen and Hertwich 2009). This approach is usually considered more appropriate for large entities such as regions, countries and cities (Wood and Dey 2009).
The literature on CF generally acknowledges that CF is a consumption based concept (Minx et al 2009), especially in terms of tourism (Munday et al 2012).

Furthemore, in the process of calculating the CF there are mainly two different methods: the bottom-up and top-down approaches. There is also a hybrid version which is a mix of both. These methods are all interrelated with the consumption based view of GHG accounting.

3.1.2 Bottom-Up Approach

The bottom-up approach is usually based on *Process Analysis* (PA) such as Life Cycle Analysis (LCA), where the environmental impacts of individual products are calculated separately – from material processing to landfill/incineration. McDonough and Braungart (2002) described the typical pathway of most produced materials to be an inefficient one-way route from cradle to grave, instead of a more efficient way of cradle to cradle.

In a bottom-up approach the effects are summed up to give an overall estimate of the impact, indicated in CO_2-eq. System boundaries must be clear and thoroughly described in order to reduce the risk of under-estimation (Wiedmann et al 2009). This method is considered to be very data heavy, particulary when the entities are large (e.g. nations and multinational corporations) and therefore it is extremely time consuming. It is more suitable on a smaller scale, e.g. for individual products where extensive LCA databases can be utilised (Wu 2011).

3.1.3 Top-Down Approach

The top-down method is usually built on *Input-Output* (IO) analysis which originated from Wassily Leontief in the 1930´s. IO analysis is based on cash flow and requires knowledge of specialized matrix calculations. For example, to calculate emissions, IO-tables use monetary information. Roughly, for each monetary unit spent in a sector, an emission is released somewhere in the supply chain (Wood and Dey 2009; Whittlesea and Owen 2012). Leontief´s Economic Input-Output tables (EIO) involved creating tables of economic accounts for particular economic sectors and then comparing them with another set of data, economic or not (Wiedmann et al 2009).

Input-Output models are usually applied on larger scales where the sectors as an entity are analysed since “it assumes homogeneity of prices, outputs and their carbon emissions at the sector level” (Wiedmann and Minx 2008, p.6). Undeniably, this can be a flaw in the methodology since emissions can be of various sizes and sorts.

IO models are not very detailed but if the right information is available, they don´t take much time or manpower. This approach is considered convenient in order to figure out the CF of governments or “a particular socio-economic group” (Wiedmann et al 2009, p.6), e.g. tourists but usually applied when a production-based view is dominant.

Australia and New Zealand have diligently used *Tourism Satellite Accounts* (TSA) in their analysis of domestic tourism sectors. TSA´s are spawned from the *System of National Accounts* (SNA) from 1993 which the *Commission of the European Communities, International Monetary Fund, Organisation for Economic Cooperation and Development, United Nations* and the *World Bank* encouraged. SNA mainly consists of a comprehensive set of accounting rules and guidelines of how to express flows of economic variables within various fields of study. The methodology and standards included in the TSA was approved by the UNWTO in 2000 (UNWTO 2013, July). It is basically a statistical tool to gain a holistic view of the tourism industry for a given area. It keeps track of demand for goods and services which are in one way or another linked to tourism. It shows production and consumption in a detailed manner and the interaction of these goods and services with other industries, both within and outside the economy of reference. However, in some cases, assumptions must be made, therefore making it not an entirely detailed appraisal (UNSD 2008).

The TSA is videly used by many different economies to estimate both direct and indirect emissions from their tourism sector (e.g. Forsyth et al 2008; Hoque et al 2010). Through the literature, when a top-down approach has been applied, a TSA has been used as the economic data against environmental accounts (Hoque et al 2010, Jones and Munday 2007).

Various offsprings of the IO method have been created, like the *Integrated Economic-Environmental Account* (IEEA) applied by Becken and Patterson (2006), which, through the United Nations *System of Environmental-Economic Accounting* (SEEA), is a “multipurpose conceptual framework for understanding the interactions between the economy and the environment, and for describing stocks and changes in stocks of environmental assets" (EC et al 2012, p.x).

There is also the *Multi-Regional Input-Output* (MRIO) method where places of production and consumption of items are analysed thoroughly and responsibility for CO_2 emissions is allocated to relative countries, thus including emissions sourced from international trade (e.g. Wood and Dey 2009; Hertwich and Peters 2009).

But scientists continually seek improvements when analysing and therefore hybrid versions have been created.

3.1.4 Hybrid version

A hybrid approach is sometimes considered to be the best approach as it can combine the sectorial data from EIO and process specific data from LCA. Based on the combination, a comprehensive and detailed analysis can take place (STF 2012).
Filimonau et al (2013) created a hybrid DEFRA-LCA method for a standard holiday package in Portugal as an attempt to make a holistic approach to calculating the CF of tourists. However, some uncertainty is bound to come up in all of the previously mentioned methods as assumptions have to be made, especially for products and services. Precise calculations and final-results are therefore difficult to truly establish (STF 2012).

In tourism impact analysis all of the above mentioned approaches have been applied in one way or another. Input-Output analysis seems to dominate with the assistance of local TSA. In many cases there seems to be a mixture of both the production and consumption based approaches (Dwyer et al 2010, Hoque et al 2010).

3.1.5 Guiding method

The relevant analytical approaches and terminology has now been briefly described. In this section the research done by Becken and Patterson from 2006 on the tourism industry in New Zealand will be introduced, but their bottom-up methodology is used as a guideline in this research. Their study is well known and documented in the tourism CF arena. They used both top-down analysis with the assistance of environmental accounting and bottom-up analysis on the tourism industry as a whole. Becken and Patterson (2006) acknowledged that consumption defines the tourist. Their method consisted mainly of assessing the energy use of tourism-characteristic industries (expressed in heat content via Joules), and then converting this figure into CO_2 emissions. Other GHG emissions were excluded from their research. They focused primarily on direct emissions while, however, the top-down approach inevitably involved some indirect emissions.

Becken and Patterson (2006) identified three tourism-characteristic industries that are in keeping with New Zealand´s TSA; i.e:

- Passanger transport
  (Road, rail, water, air, other, transport services and equipment hiring)
- Accommodation
  (Including catering services)
- Tourist attractions
  (Cultural and recreational services)

The boundaries applied in their analysis were national boundaries, therefore leaving out international flights. The retail-trade was also excluded altogether and deemed a "tourism-related industry" (Becken and Patterson 2006, p.326) thus excluding travel-agencies as well. They also excluded restaurants and other catering services, mostly due to the time consuming process of retrieving data.

When they constructed their bottom-up analysis on the tourism industry, they relied on measuring the energy intensity of specific sectors within it, and from that the sectors' CO_2 emissions could be estimated. The energy needed for the varying travel behaviour of tourists was individually documented in a model, which eventually gave a total picture of the energy needed across each sector. The information on various tourism behaviour was derived from two different visitor surveys, one from international tourists and another from domestic tourists. Included were detailed itineraries of accommodation choices, travel modes and distance travelled. Typical tourist types were then derived with cluster analysis through the two visitor surveys, which is when groups with similar behavioural patterns are found and compared with the patterns of another group. Becken and Patterson also claimed that in order to get a meaningful comparison between visitor types it is important to have the same overall trip length.

A top-down analysis was done by using environmental accounting – or the IO matrix called Integrated *Economic-Environmental Accounts* (IEEA). Becken and Patterson used TSA data and energy data from relevant authorities for 1997 and 1998, which was then inserted into a model. Their intention was to include only direct emissions, but inevitably by applying a top-down approach which relies on the usage of general multipliers, some indirect effects were bound to be incorporated to some extent.

Becken and Patterson concluded that both approaches – top-down and bottom-up, reach a similar conclusion as to how much tourism, both from domestic and international sources, contribute to New Zealand´s national CO_2 emissions.

However, the Becken and Patterson (2006) study cannot be used directly for this research due to limited data and time restraints. Therefore, other supportive material and models were needed in order to build a credible picture.

3.1.6 Supportive material and models

In order to answer the research questions set out in the first chapter, other analytical methods will also be incorporated into this study.

The Travel Foundation, with assistance from Dick Sisman and Associates (2007), developed a methodology for tourism companies and destination places to calculate their carbon footprints. It focuses on energy consumption, especially from hotels and food preparation/provision. It is a bottom-up approach since Sisman and Associates believe that the method gives a better picture of the individual components, which is important so as to identify hot spots for energy savings. The method involves identifying the relevant activities (e.g. lighting, heating, transport etc) and their individual energy consumption, before assigning a CO_2 emission factor according to the *UK Department for Environment, Food and Rural Affairs* (DEFRA 2012) or IPCC guidelines (2006). Sisman and Associates provide a table as an example of this calculation methodology and their intention is that the same approach can be applied anywhere to build a regionally specific table. After each activity has been analysed, a small textbox follows where suggestions of improvements (via mitigation measures) are made.

De Bruijn et al (2012) have calculated the CF for Dutch holidaymakers, both domestic and outbound, on six different occasions. Quantitative information on Dutch behaviour as tourists was retrieved with a comprehensive survey performed annually. It analyses primary (direct) CO_2 emissions and emissions from energy production, e.g. fuel and electricity. The research focuses on transportation, accommodation and organised versus non-organised holiday tours. Its main results are that the average Dutch carbon footprint abroad is 62 kg CO_2 per day and 25 kg CO_2 per day domestically, while ranging from 29 kg (in Belgium) to 169 kg (in rest of Americas, other than USA and Canada) CO_2 per day. The De Bruijn et al study seems to be ambitious and thorough. Its setup will be used as a reference point in this study because of its clear view and focus, assisted by many charts and tables.

The study done by Becken et al (2003) is also a supportive study, where tourists were cluster-analyzed and segmented into seven different types according to their travel pattern. All types behaved differently, thus having different CF. The tourist’s choices are therefore important to the CF calculation since they have different energy intensities. It is obvious that tourists who chose to travel with bicycles, eat locally produced food and stay in tents have a much lower CF than those who travel with a private car, dine on exotic food in restaurants, and spend their nights in lavish hotels.

Nonetheless, these studies and supportive material are not free from criticism and can be improved.

3.2 Criticism and improvements

It is important to view matters from both sides and offer criticism. Thus, an opportunity for improvement emerges.

The study done by Becken and Patterson (2006) was a reconstruction of Patterson and Mcdonald´s study from 2004. Their method has also been replicated to partial or full extent by other researchers previously mentioned, such as De Bruijn et al (2012) and Perch-Nielsen et al (2010). Usually some improvements or adjustments are involved when the method is used by others, and here are some of the main notes of the criticism that it has already received.

Gössling (2013) mentions that the CO_2 quantity calculated in Becken and Patterson (2006) isn´t put into any perspective, i.e. with respect to total national emissions. That risk has already been eliminated in this study.

In the Becken and Patterson (2006) study a national border was drawn, therefore excluding the impact of international air travel. The main reasoning was risk of double counting (e.g. global bunker-fuel monitoring of ICAO), but Whittlesea and Owen (2012) do not concur with that approach. They believe that all air travel must be incorporated so that consumers/tourists can take an informative decision on ways to cut back their CO_2 emissions. This assertion is fully accepted in this study and international flight incorporated into this studys´ research boundaries.

Dwyer et al (2010) have several notes on the approach. They are not content with the fact that Becken and Patterson (2006) leave out some sectors of the tourism industry and focus on others. To Becken and Patterson´s understanding, tourism "characteristic industries comprise accommodation and catering services; road, rail and water passenger transport; air transport; other transport and transport services; equipment hiring and cultural and recreational services" (p. 358) but catering was excluded due to time limitations. Dwyer et al (2010) would like to include restaurants and other catering services into the calculations along with "tourism-related industries" (e.g. tour office administration etc). It shall be noted here that data availability and the set timeframe for this study created a limitation, which led to the decision that restaurants and catering services were excluded.

Dwyer et al (2010) also object to limiting the calculations to only CO_2 emissions from the direct impacts of tourism. In order to give a "complete picture of tourism's carbon footprint" (p.358), both direct and indirect emissions must be calculated. However, since Wiedmann´s and Minx´s (2008) definition of the CF is fully agreed upon here, only CO_2 will be calculated in this carbon footprint analysis.

The scope of this research is simply direct emissions as indicated by the DEFRA (2012) framework and IPCC guidelines (2006).

Regarding the trip durations, despite the suggestions and approaches made by Becken and Patterson (2006) on the overall trip lengths (for them to be all the same), the hypothetical scenarios in this analysis will have different lengths in order to follow the data and attribute a realistic carbon footprint per day to each tourist type, as described in the objectives of this research.

3.3 Research Boundaries

Gössling et al (2013) stated that it is not simple to calculate GHG emissions from tourism. Consequently, the authors stress the importance of thoroughly explaining the research frame and data. Next, the geographical boundaries will be described followed by the general scope of the research. The relevant tourism sector is portrayed along with units and the level of analysis. Finally, the relevant timeframe and data acquisition will be set out.

3.3.1 Geographical boundaries

The tourism experience of Iceland will be an evaluation period - from the time the tourist sits in his seat in the airplane/ship, until he steps off from it again at the same location a few days/weeks later. During that time, through his consumption choices, the tourist will directly emit a certain amount of CO_2 into the global atmosphere. Thus, national borders are somewhat the boundary but including the total international air/marine travel, both ways. For an island destination it is expected that the most significant hotspots will be the international transportation to and from Iceland in this case (see Becken 2002 and Gössling 2000, 2002) in Dwyer et al (2010)). This approach was preferred due to the international transportation significance to the impact appraisal and the fact that it is included in the De Bruijn et al study (2012).

In Figure 3.1 the boundaries are depicted. The blue box on the left shows what is inside the boundaries and therefore included in the CF calculations, i.e. both the international and domestic transportation modes along with the relevant electricity usage. An effort was made to estimate the gas usage of tourists within Iceland, however only gas used in fireplaces and for warmth purposes, not restaurant/catering activity.

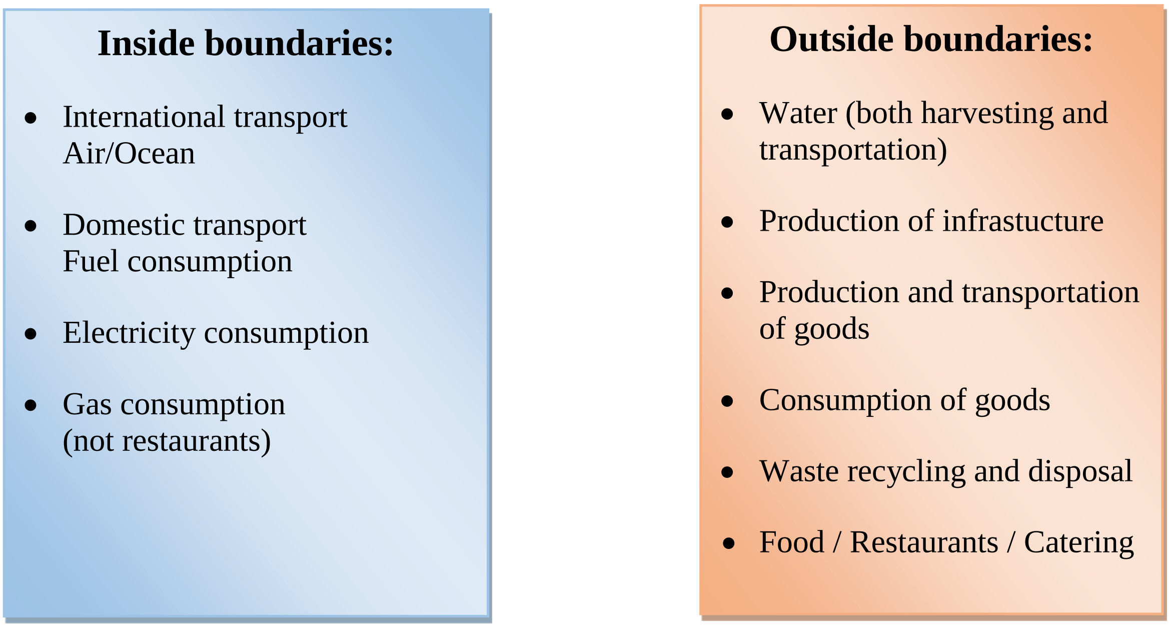
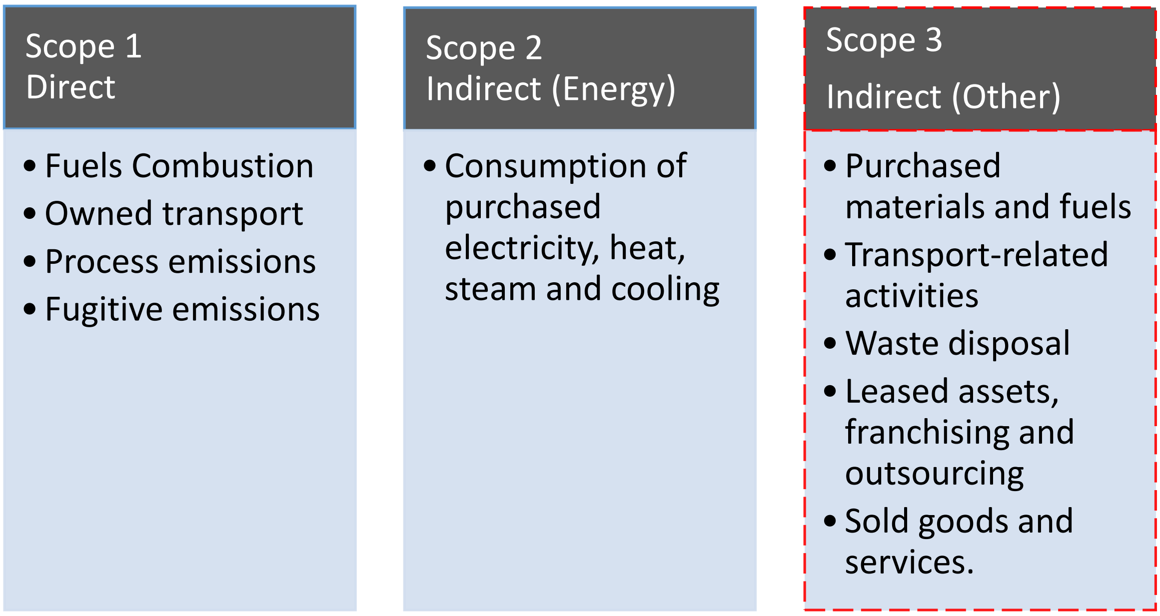


Figure 3.1 Boundaries of this Carbon Footprint analysis

The orange box on the right depicts what is outside of the boundaries of this research, i.e. all water usage, both for harvesting it and transporting it. However, it is debatable if hot water is to some extent included in the electricity production via geothermal, but the general approach involved that water was not encompassed. With this studys´ research period in mind (roughly three months), all production of goods was left outside of the boundaries since it would have been too time consuming to do an LCA on all products used in one way or another by tourists in Iceland. In terms of recycling and disposal of the waste tourists leave behind, it was also left outside of the boundaries of this research due to lack of data and time.

3.3.2 Scope

The term scope involves the evaluation of what emissions to incorporate into the calculations.
In the DEFRA (2012) guidelines the scope is categorized according to the GHG Protocol (2005) in three different parts.



Source: DEFRA 2009

Figure 3.2 Overview of scope 1-3 emissions

Figure 3.2 provides a brief overview of scope 1, 2 and 3 emissions. Scope 1 emissions are generally referred to as direct impact, the emissions that occur directly from an activity an individual has control over. This involves energy consumption, e.g. use of combustion fuels for transportation, boilers and furnaces under human direct control. Air and sea travel also fall under this category, since it is a matter of transportation choice made by the traveller. Scope 2 emissions are referred to as indirect emissions. These are the emissions created by electricity generation, either by liquid fuel combustion, heat, steam, hydro- or geothermal power. Energy has been created somewhere else and brought to the place of consumption. Scope 3 emissions are also referred to as indirect (sometimes induced) emissions. This is basically the rest which have not been mentioned in scopes 1 and 2. It can involve production of products and the extraction of materials to produce them. It can also involve various services in providing the product, such as housing and transportation.

In the Becken and Patterson (2006) study, direct impacts are referred to as "those that result directly from tourist activities, while indirect impacts are associated with intermediate inputs from second or third (or nth) round processes" (p.324) – here *nth* simply means an unknown number in a sequence. Lissy (2012) and De Bruijn et al (2012) use the terms primary and secondary footprints/emissions when evaluating direct and indirect effects. The primary footprint includes both fossil fuels for transportation and heat/energy provision. The secondary footprint involves the indirect CO_2 emissions from the usage of various products, from their manufacture to eventual breakdown (lifecycle).

By following the previously mentioned methodology, the direct emissions along with electricity usage (scope 1 and 2) will only be calculated for the international tourists that visit Iceland.

As an island, Iceland's inhabitants are dependent on imports of various consumer goods which scope 3 emissions are calculated from, including fuel, food, beverages, clothing etc. However, CO_2 from scope 3 emissions will be excluded altogether, mainly due to time limitations and lack of data availability. Additionally, Chan (2009) recommends that if emissions from imports to meet tourism demand are not a major contributing factor, i.e. if it is less than scope 1 and 2 together, they should be left out completely.

The only imports anticipated in this studies´ calculations will be the transfer of the tourist itself. Product importation and use of consumer goods is left out despite the assumption that "exclusion of indirect emissions arising from the upstream supply chain as well as downstream disposal is very likely to bring about considerable underestimation" (Wu 2011, p.3). Imported consumer goods are simply outside the boundaries of this research.

3.3.3 Tourism sector

The tourism sector is segmented for this study into the same three main categories as Becken and Patterson (2006) and Gössling et al (2005) used i.e. transportation, accommodation and attractions/activities. The triple categorisation is also similar to a categorization described in a report constructed by the UNWTO, UNEP and the WMO from 2008, where products and restaurants were not included. The categories were:

- International air transport
- International marine transport
- Road transport
- Other transport (e.g. ferry, domestic flight)
- Accommodation
- Activities and attractions

The triple categorisation is therefore considered better suited for the local tourism environment and this type of study since limited information was available on emissions from the retail sector, restaurants and cafes in Iceland. Time limitation was also a contributing factor in the decision making process.

3.3.4 The tourist

A survey was conducted for the Icelandic Tourist Board (ITB) in the summer of 2011 by *Market and Media Research* (MMR) among foreign visitors in Iceland. There were 2,359 people out of 4,545 (51.9%) who answered the survey (ITB 2012). The answers provided are very important for the tourist catagorisation process and also for building the CF model for foreign visitors in Iceland. There was a similar survey conducted during the following winter but Icelands main tourism season is in the summer months when the availability of different activities and attraction sites reaches its peak. Therefore, one can assume that tourist behaviour during the cold winter months is quite different from the summer months.

In the ITB-survey (2012), tourists were asked several socio-demographic questions about themselves, e.g. age, income, job etc. There were also many questions about the tourism experience and activities during their trip, for example length of stay, their accommodation choices, transportation methods and expenses, to name only few questions whose answers will assist in understanding the tourists´ consumption choices. In Table 3.1 the main characteristics of the typical tourist that visited Iceland in the summer of 2011 are depicted.

Table 3.1 The most typical tourist that visited Iceland in the summer of 2011

Gender*	Female (51.2%)	Males (48.8%)
Total average age	39.6 years	
Income	Average	(39%)
Travel companion	Spouse	(42%)
Purpose of trip	Vacation	(86%)
Trip organiser	Self-organised	(80%)
Trip duration	10.2 nights	
Domestic travel mode	Rental car	(46%)
Accommodation	Hotels/Guesthouses	(77%)
Most popular region	Capital area	(92%)
Most popular place visited	Golden Circle	(72%)
Average expenditure**	186,600 ISK***	

* Of those who answered the survey (n=2,359)
** Excluding airfare/ferry and prepaid tour packages.
*** Exchange rate on July 1st 2011; 114 ISK/$ or 166 ISK/€ (Central Bank of Iceland 2014).

The distribution between males and females seems to be fairly even, at least of those who answered the survey. Average age of the total was 39.6 years and most consider themselves to be in the average income category, compared to average income in their home country. This tourist plans his trip himself and the purpose is mainly vacation with its spouse for 10.2 nights. Most tourists chose to travel with a rental car (46%) and stay at hotels or guesthouses (77%). Most tourists visited the capital area (92%) and tour the Golden Circle (72%), i.e. Gullfoss, Geysir, Þingvellir etc. The average money spent per person (excluding international transport) is 186,600 ISK or roughly €166 according to the exchange rates in July 2011 (Central Bank of Iceland 2014).

In this study it is assumed that most consumption choices are interlinked with rises in wages (explained later), i.e. more expensive choices are made among those who have higher income, since the data from the ITB-survey supports that understanding in great detail.

With the typical/average tourist in mind, three tourist types will be considered: low, medium and high consumption choices. Each type will be inserted into hypothetical scenarios, largely supported by the data available. In section 4.1 the tourists used in this analysis and appropriate assumptions will be described in more detail.

3.3.5 Timeframe

The timeframe for this research is the summer of 2011, the same timeframe as the ITB survey was conducted in order to most accurately reflect the answers provided then.
The CF is calculated for a 7, 11 and 16 (+4) night round trip around Iceland anytime between June 1st and August 31st. In some cases data was not obtainable for that specific year/summer, for example from many hotels. In those cases, available data from the period closest to 2011 was used.
The research period for this study was from late December 2013 to late March 2014. The thesis was mostly carried out at the end of July 2014.

3.3.6 Data

The data acquisition for this survey was based on previous research projects found on the internet within recognised and peer-reviewed journal publications. The search word was simply “Carbon Footprint” to begin with and gradually the search words multiplied covering both various methods, reports and research areas. Reference lists on individual articles created a snowball-effect until the literature on the subject was believed to be scanned well enough to start modelling the approach taken in this study. Published books were also used to some extent, while primary data acquisition was considerable from sources such as e-mail correspondence, phone-calls and interviews with relevant informatives.

It would have been ideal to use a TSA, but the last TSA available from Icelandic Statistical office (Icestats) is only valid for 2009 and it is not known when it will be issued next due to lack of funding. TSA for 2012 and 2013 was made by Gekon (2013), an Icelandic consultancy agency specialised in clusters and strategy management but it isn´t as detailed as the Icelandic Statistical office was obligated to produce. Furthermore, the specialized matrix calculations skills were not available to apply a top-down approach from TSA´s. Tourism arrivals to Iceland have also increased considerably between the years 2009 and 2011, by roughly 14.5%. Thus, the official but outdated Icelandic TSA and the Gekon TSA´s were ruled out for use in this study given the timeframe used. In the light of that, it was decided not to follow the methodology from Becken and Patterson (2006) alone but supplement and strengthen it with the other methods previously mentioned.
Nevertheless, much important and valuable information for conducting this research is retrieved from Icestats database, e.g. GDP, foreign currency and much more, which are also used for constructing a TSA.

Information on energy use was gathered from various accommodation providers as well as attraction/activity and transport operators in Iceland. Many people showed interest in this research and agreed to contribute information for its benefit. The hope was to receive enough answers to build a useable emissions table for these sectors, but unfortunately this was not possible since a limited number of people replied to the request with useable data - despite repetitive but polite encouragement from the researcher. Many stated that they did not necessarily monitor this and the work behind it was far too onerous. Eventually, the timeframe of the study limited the answering rate even further.

Acknowledged emission factors are provided by the *UK Department for Environment, Food and Rural Affairs* (DEFRA 2012), which is considered to be a key reference when calculating the CF of tourism products and services (Filimonau 2013). The IPCC *Guidelines for National Greenhouse Gas Inventories* (2006) and the GHG Protocol (2005) are also used. In some cases, country specific factors must be accounted for, e.g. the CO_2 from electricity production.

Furthermore, the previously mentioned ITB-survey conducted among foreign visitors in Iceland in the summer of 2011 proved to be vital for this study. All the statistical analysis in the following chapters is built on information from that survey, unless otherwise noted. It would have supported the purpose of this research to get access to Markets and Media Research´s (MMR) raw data on the ITB-survey. For example, the spreadsheets and individual answers from its 2,300 recipients could have assisted in creating a detailed cluster-analysis of the tourist. It could also have helped to process some of the answers in a statistical analysis tool such as SPSS to narrow their focus down to this topic and to cross-examine the answers to one question in relation to another. Nevertheless, due to laws on personal privacy, MMR was not able to grant this request.

Finally, data on pure CO_2 emissions due to electricity production in Iceland was sorely missed. General GHG (CO_2-eq) calculations exist on overall production but were not specified down to kWh. A bold attempt, supported by actual data, was made to give the average Icelandic kWh a CO_2 value.

3.4 Summary

In this third chapter the material used for this analysis was described. The background of carbon footprinting was briefly analysed to gain perpective along with short descriptions of previous studies and definitions, including the consumption and production based view of responsibility of GHG emissions. The bottom-up approach of estimating GHG´s is considered more tedious than the top-down approach but more thorough, depending on the data used. Numerous combinations of these two methods have also emerged, individually called a hybrid-version but the purpose is usually an effort to create a more detailed method of calculation. The guiding method behind this analysis was described, i.e. the Becken and Patterson study from 2006 where they applied both the top-down and bottom-up approaches. However, only the latter method will be followed in this analysis along with other supportive material e.g. Sisman and Associates (2007) and De Bruijn et al (2012).

The main criticism and disappointment is severe lack of data to be able to build a detailed CF, but an estimate must be sufficient for now. One of the main changes from the guide-study was that trip lengths did not all have the same duration, but this actuality is believed not to have an effect on the end-result, which is a CO_2 weight per day for each tourist type.

The research boundaries were described, i.e. direct emissions (scope 1 and 2, primary) from tourist choices during the total tourism experience, from departure to landing at the same starting point. The tourist, through his consumption choices during his overall trip, emits CO_2 into the global atmosphere. The amount of CO_2 which will be estimated here. The main focus is therefore on energy and fuel consumption within three tourism sectors: transportation, accommodation and attractions/activities. The typical tourist was described as a 39 year old of average income who travels with their spouse in a rental car for 10 days. From the answers provided by roughly 2,300 recipients of a survey by the Icelandic Tourist Board (ITB) conducted in the summer of 2011, three tourist types will be described and inserted into hypothetical scenarios. Various other information on emissions factors and relating calculations, sourced from DEFRA (2012) and IPCC Guidelines (2006), were important contributors to the calculation methodology undertaken in this project.

In the next chapter the appropriate methodology applied in this research will be thoroughly described.

4 Methods

As previously mentioned, this study focuses on a bottom-up analysis of direct emissions from tourists in Iceland. From the behavioural information retrieved from the ITB-survey (2012), foreign tourists in Iceland were categorised. By analysing the answers from relative age and income groups, their consumption behaviour was mapped and three hypothetical scenarios were constructed – low, medium and high consumption. The direct CF was then calculated for these three scenarios with an emphasis on transportation, accommodation and attraction/activity choices. Figure 4.1 describes the process of analysis for the tourist behaviour which will be further explained in the next sub-section. Firstly, the threefold tourist categorisation will be described and rationalised. The consumption choices of all three tourist types will then be traced and highlighted within each scenario.

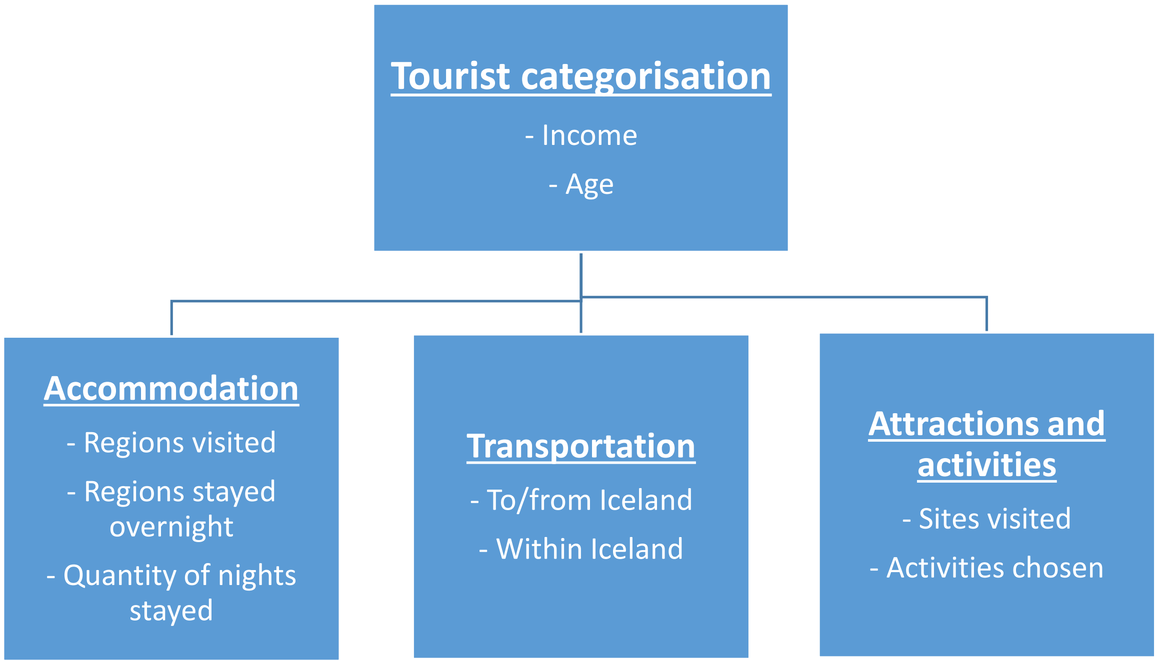


Figure 4.1 The process of analysis for ITB-tourist behaviour

4.1 Tourist categorisation

The core of the categorisation is built on the responses concerning income, in relation to average income in the tourists own home country. Five categories were optional in the ITB-survey: low, below medium, medium, above medium and high income. In this analysis the two extreme ends – low and high income – represent the low and high consumption tourist, while the medium income tourist will represent the most typical tourist, or the medium consumption one. A brief summary of the tourist categorisation can be seen in Table 4.1 below. The reasoning behind this specific categorisation is that individual travel choices seem to differ between tourists according to their income.

This assumption on consumption is in accordance with the findings of Bayar and McMorrow

(1999), who analysed the post-Keynesian *consumption function* where interest rates, savings and income were suggested as the main drivers behind consumption. Bayer and McMorrow generally agree that many households make their current disposable income steer many decisions regarding personal consumption.

According to the results of the ITB-survey, those who have higher income seem to spend less time in Iceland, but somehow are able to experience most of the conventional tourism activities Iceland has to offer. The manager of Hamrar, a large camping ground in the north of Iceland, said that his feeling was that tourists are generally staying shorter in Iceland and are usually in a big hurry to see as much as possible in as short time as possible (Tryggvi Marinósson, personal communication, April 3rd 2014).

As previously mentioned, Icelandic tourism industry relies heavily on Scandinavian, English, European and N-American markets, and these markets are also reflected in the survey. However, with these well developed and overall prosperous countries in mind, it is assumed that consumption behaviour is broadly unrelated to nationality. Age can, however, be a relevant factor since Table 4.1 gives reason to assume that income increases with higher age, since the low consumption tourist is usually a young student, while medium and high consumption tourists are older professionals whose life responsibilities seem to increase as they get older. Therefore age is sometimes used to level off the low, medium and high consumption tourists.

Table 4.1 Summary of tourist categorisation

	Low	Medium	High
Age (Years)	26.6	38.7	46.5
Income (compared to average income in home country)	Low	Average	High
Trip duration (nights)	16 (+4)	11	7
International travel mode	Ferry	Flight	Flight
Domestic travel mode	Bus	Regular car	Car - 4x4
Travel companion	Spouse	Spouse	Spouse
Profession	Student	Professional / Specialist	Professional / Manager

The medium consumption tourist is about 39 years old and arrives by flight as well as the high consumption tourist who is eight years older. The low consumption tourist is the youngest of the group, a little less than 27 years old. This tourist arrives with a ferry but his main domestic mode of transportation is with a bus, while the others use rental cars of different sizes. They all travel with their spouse and the trip duration in Iceland varies from 7-16 nights, which will be explained later.

Figure 4.2 depicts the average expenses of each tourist type during their whole trip within each tourist sector. The numbers are derived from the ITB-survey. It also includes *other transport costs (*e.g. fuel, maintenance etc.) since it was believed to be interlinked with the transportation expenses.

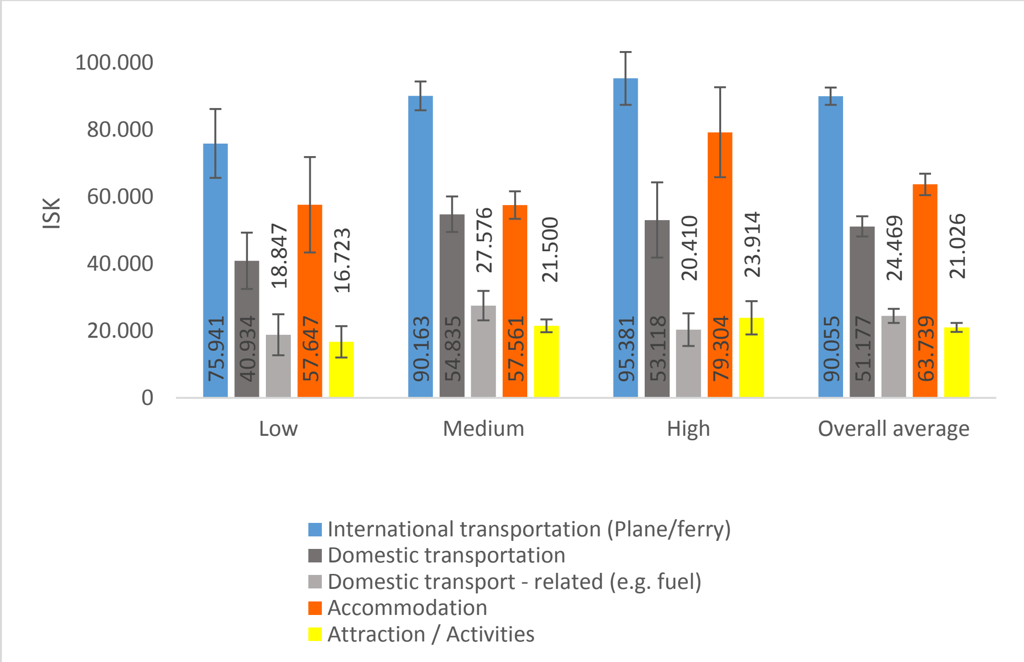


Figure 4.2 Average tourist expenses in the relevant sectors by ITB-respondents

High consumption tourists spend the most on their international airfare ticket, or 95,381 ISK, medium spends 90,163 ISK, and low spends 75,941 ISK. Low and medium consumption tourists seem to spend similar amounts on accommodation, with 57,647 and 57,561 ISK respectively. Here, the low consumption tourist spends 86 ISK more than the medium consumption one, while high consumption tourists spend the most: 79,304 ISK. The low consumption tourist spends the least on domestic transportation and transportation related material: 40,934 and 18,847 ISK respectively. Surprisingly the high consumption tourist spends the second most: 53,118 and 20,410 ISK respectively but this tourist also has the shortest trip. It is the medium consumption tourist who surpasses them both by spending the most on domestic transportation and related material: 54,835 and 27,576 ISK respectively. The high consumption tourist does however have a larger range (+/-) on the average deviation than the medium consumption one does in transportation: 11,360 opposed to 5,310 ISK. Expenditure on attractions/activities seems to rise alongside higher income, but all tourist types seem to spend similar amounts on attractions/activities: in the range 16,723 up to 23,914 ISK. Most medium consumption tourists did not deviate much from their average of 21.500 ISK, or +/- 1,924 ISK, but both low and high had a range of +/- 4,683 and +/- 4,955 ISK respectively.

The three categories of tourists were briefly introduced in Table 4.1. In the following sub-sections, a more thorough explanation is given on how all three tourist/consumption types were categorised, based on the information attained in the ITB-survey.

4.1.1 Low consumption tourist

In the ITB-survey, 2,359 people answered the question on transportation type to Iceland. The majority arrived by plane, or 93.3% while only 6.1% arrived on board an international ferry (see Figure 4.3). It can be noted here that 67 cruise ships arrived in Reykjavík in 2011 (Associated Icelandic Ports 2013), but Figure 4.3 only applies to the responses made by ITB respondents who arrived with the international ferry Norröna.

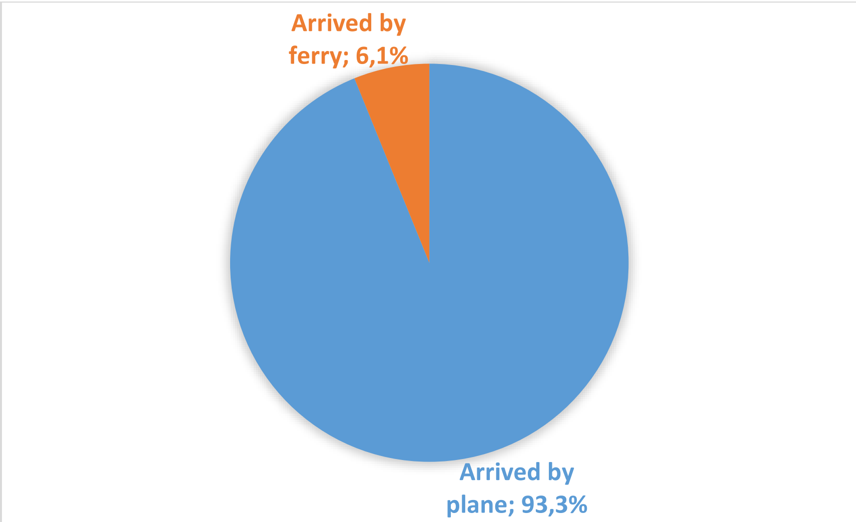


Figure 4.3 Transportation modes to Iceland by ITB respondents

Norröna is both a cargo and passenger ship (see Figure 4.4). It is operated by Smyril Line from the Faroe Islands and links the Icelandic port of Seyðisfjordur in the east with the mainland of Europe through Denmark (Hirtshals), with the Faroes (Thorshavn) in the middle.

According to ITB respondents, precisely 12.8% of Norröna´s overall passengers are students, and since it has been established that low consumption tourists have a tight budget but can stay for long periods, it is assumed for the purpose of this analysis that this tourist is a backpacker from mainland Europe.

The low consumption tourist most often travels with its spouse, 27.8% of the time.

Source: Smyrilline.com

Figure 4.4 Smyril Line´s Norröna at sea

This tourist is the only one out of the three who arrives and departs by international ferry. This tourist has a low income and his travel choices reflect that. The ITB-survey supports this analysis. Perhaps the largest anomaly emerges when the incomes are analysed, since the majority of guests arriving with Norröna consider themselves to be in the medium or above medium income category compared to average incomes in their own country: 45.5% and 31.6% respectively. Only 5.4% consider themselves to be in the low income category and 13.3% below medium. The average age in the low income category is 26.6 years, (with a deviation range (+/-) from the average of +/-1.6), which is consistent with the majority of passengers on the Norröna, where 27.6% are between 25-34 years, according to ITB respondents.

It shall be noted at this point that the choice of travel mode for low consumption tourists in this analysis is not a generalization for all low income tourists. It is simply used for analytical purposes in this specific hypothetical scenario in order to include both major transportation modes to and from Iceland.

The majority of those who arrive with Norröna (42.6%) chose to stay more than 15 nights in Iceland, with an average holiday period of 17.7 nights (+/- 1.9). This is consistent with those who consider themselves to have low income, because 26.3% stayed more than 15 nights with an average length of 14.5 nights (+/-3.8). Therefore, the average between 17.7 and 14.5, or 16 nights, is considered the typical length of stay for our backpacker-tourist. It makes sense that a young person travelling around Iceland with only a backpack and perhaps a bus card would take longer to travel around the country than those who have a rental car.

Here, a question of trade-off emerged since there are 7 days intervals between Norröna´s arrivals/departures but the hypothetical route is 16 nights (explained later). It was decided that the CF calculation should be based on typical tourist behaviour during a typical length of stay inside Iceland, and that this was much more important than making the arrival and departure dates fit exactly with the vessel's actual schedule. Besides, the CF for Norröna would always be the same despite the individual tourist´s duration of stay in Iceland. Furthermore, due to the ship's travelling time, which is four nights in total, it will be added to the tourists´ *on-land* duration in the results-section where their emissions per day are calculated.

4.1.2 Medium consumption tourist

This tourist is one of 2,216 people (93.3%) who arrived by airplane and answered the ITB-survey. Keflavik Airport on the Reykjanes peninsula is the country´s largest international airport, where most of inbound tourists arriving by flight land. There were approximately 15 airlines who operated passanger flights to Iceland in the summer of 2011, among them where the Icelandic airliners – Icelandair and Iceland Express (now WOW Air). However, the default airliner for the international flight used in the CF calculations was the North-American based Delta Airlines, which also flew to Iceland in 2011. It was chosen because it uses a very similar airplane to the one used by Icelandair, the main Icelandic airliner, and because information was more accessible from Delta Airlines.

For the purpose of this analysis, and largely supported by the data, it is assumed that the medium consumption tourist is from the centre of Europe, departing from Frankfurt in Germany, a large airport hub where travellers from neighbouring areas gather. This tourist is one of 39.3% of those who answered the survey stating that they receive average income compared to average wages in their home country. The tourist is 38.7 years old on average (with a deviation range (+/-) from the average of +/-0.9) and usually travels with their spouse (43.9%), in a rental car (self-drive). This tourist is most likely a professional (28.5%) or worker with some sort of specialized skill (23.9%). It is assumed that this tourist takes a bus from Keflavik Airport to Reykjavik city and back again after his stay.

This tourist stayed on average 10.4 nights (+/-0.7), while the majority (25.6%) stayed 5-7 nights and 23.3% stayed 8-11 nights. Most of those who arrived by flight stayed 9.7 nights (+/-0.5) on average. In this analysis, it is assumed that the hypothetical route this tourist travels takes 11 nights. This tourist’s trip duration was mostly built on the assumption that when tourists are in the capital, they don’t use rental cars but instead find cheaper ways of transportation, e.g. taxis or buses. Those who have medium income stayed on average 4.3 (+/-0.5) nights in the capital while a representative of a large car rental, Benedikt Helgason from *Thrifty* (personal communication, January 28th 2014), claimed that their average car rental period (in this case for cars used outside the capital) was 7.7 days (= 7 nights), which sums up to 11 nights (7+4) when the capital nights are combined with it.

4.1.3 High consumption tourist

For the purpose of this analysis it is assumed, and largely supported by the data, that the high consumption tourist arrives by plane from North-America – New York in this case. This tourist takes a taxi from Keflavik Airport to the capital, but thereafter he is also a self-drive tourist. The travel choices of this tourist reflect a demand for more luxury and comfort than low and medium consumption tourists. However, this tourist decided to take the airport bus, when he leaves.

This tourist is one of 9.5% who answered the survey stating that they receive high income compared to average wages in their home country.

This tourist is 46.5 years old on average (with a deviation range (+/-) from the average of +/-1.8) and travels with a spouse 48.3% of the time. This tourist is most likely a professional of some sort (47.1%), or attains a managerial position (23.9%).

This tourist stayed on average 7.5 nights (+/-0.7), while the majority (25.5%) stayed 5-7 nights and 21.4% stayed 3-4 nights. A similar method as in the case of the low consumption tourist was used to derive the overall number of nights, but with similar information as per the medium consumption tourist. The average between the typical car rental period (7.7 days or 7 nights) and his average number of nights stayed in Iceland equates to the typical length of stay for the high consumption tourist at 7 nights ((7.5+7)/2=7.25).

4.2 Transportation

In the following analysis seven different modes of transportation are used in the hypothetical scenarios. The modes do not all apply for each scenario but interchange between them.

The transportation modes are:

- Airplane – Boeing 757-200
- International ferry; Norröna – Smyril Line
- Scheduled buses/coaches (backpackers)
- Coach – airport-bus and tour bus
- Rental cars – Ford Fiesta and Ford Explorer
- Shuttles – Activity pick up´s
- Taxi´s

Private cars are excluded for the following reasons: firstly, there was no supportive data found to build the hypothetical use and distance travelled on private cars. Secondly, a private car should emit the same CF as a rental car, given it is not a very old model or with an inefficient engine.

Once the tourists are in Iceland, all three tourist types will more or less travel on Iceland´s ring road number 1 (seen on Figure 4.5) which is a 1,332 km long public road (IRCA n.d.).

It should be noted here that when it came to constructing the hypothetical routes around Iceland, the Reykjanes peninsula, Vestfjords and central highlands were intentionally left out of the calculations. This is rationalized by the very low percentage of visits 15.1%, 12.3% and 18.1% of the total respectively, (see Table 4.3) and also due to the fact that these regions are mostly outside Iceland´s ring road number 1. However, it is quite possible that tourists take a day-tour to the Reykjanes Peninsula, since one of Iceland most popular attraction sites, the Blue Lagoon, is to be found there. In 2011 it received 459,000 visits from both Icelanders and foreigners – but the majority were foreign (Grímur Sæmundsson 2012). In the ITB-survey from the same year, the Blue Lagoon was chosen as the second most memorable place visited by its respondents.

Source: Trex.is 2010

Figure 4.5 Icelands Ring road number 1

When it comes to transportation methods within Iceland, most people prefer rental cars, since 46% of those who answered the survey used them while they stayed here. A further 37.2% used scheduled buses and 36.2% used tour buses. Another 15.6% used taxis, 12.8% travelled by private cars, 9.1% used domestic ferries, 6.4% used domestic flights, 4.8% used bicycles, and 9% used other modes of transport. Note that ITB-respondents were able to indicate more than one transportation mode during their overall stay.

4.2.1 Low transportation choices

The low consumption route starts in Hirtshals, Denmark onboard the Norröna-ferry, which can take 1,482 passengers, 118 crew members and 800 cars. Its total capacity is 3,250 t. Norröna burns heavy fuel oil (HFO) with 1.0% sulphur content. The typical fuel consumption of Norröna in the summer months is 450 t per week during its weekly journey between Denmark, Faroe Islands and Iceland (seen in Table 4.2). It is a route comprised of 1,921 kilometers. Norröna refuels only in the Danish port of Hirtshals (Smyril Line n.d.,a).

Table 4.2 Norröna summer schedule

Weekday	Port
Saturday	Hirtshals (Denmark)
Sunday	Thorshavn (Faroe Islands)
Monday	At sea
Tuesday	Hirtshals
Wednesday	Thorshavn
Thursday	Seyðisfjordur (Iceland)
Friday	Thorshavn

After the ferry arrives in Seyðisfjörður, the low consumption tourist mostly uses a scheduled bus to travel around Iceland. The most preferred transportation mode among those who consider themselves in the low income category is scheduled buses (50.5%). Other popular transportation choices were rental cars (35%), tour buses (32.3%) and private cars (23.4%). This fits nicely when the answers from Smyril Line passengers are compared, but after private car the second most popular travel mode among those passengers are scheduled buses (23.7%). It is anticipated that backpackers would use scheduled buses, but it is also anticipated that they walk some part and then hitchhike.

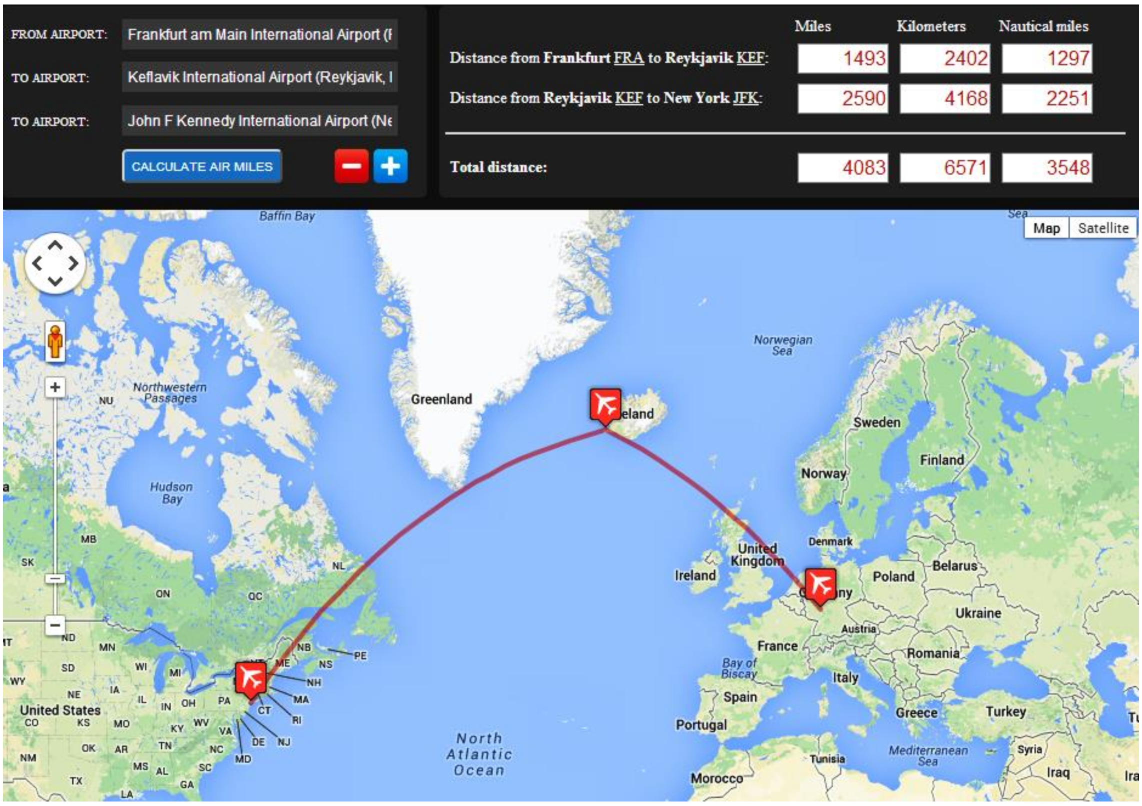
As shown in Figure 4.6 this tourist mostly follows ring road number 1 clockwise from Egilsstaðir (checkered bubble), with the exception that when he comes close to Selfoss in the south, he heads north towards the Gullfoss and Geysir area (bubble 1), which is a very popular area among all tourist types. Afterwards, he travels west towards Þingvellir and then through Mosfellsheiði towards Reykjavik. This particular route was chosen since both 64% of those who consider themselves to have low income and 85% of those who arrived with Norröna visited this site according to the ITB-survey.
The route, Gullfoss-Geysir-Þingvellir, is commonly labelled the 'Golden Circle' among tour operators in Iceland.

Figure 4.6 Low consumption tourist´s route around Iceland

According to the internet map service *Here.com* the route travelled by the low consumption tourist in scheduled buses is 1,401 km. There is nothing extra added to the low consumption route since it is assumed that backpacker travellers will walk to some extent but will also try to hitchhike occasionally, which will consequently be assigned to that particular vehicle, whether they are tourists or not.

4.2.2 Medium transportation choices

There are two international airports relavant to this study, *John F. Kennedy* (JFK) in New York, USA and *Frankfurt am Main* (FRA) in Frankfurt, Germany.
According to the website *airmilescalculator.com* the distance from Keflavik Airport in Iceland to these two airports is 4,168 km and 2,402 km respectively (see Figure 4.7). The distances must also be expressed in nautical miles (nm), since CO_2 calculations from air-travel in this case depend on that. According to the Carbon Neutral Calculator (2012), the JFK-KEF flight would be categorized as a long-haul flight (+3,700 km) and FRA-KEF would be a medium-haul flight (785-3,700 km).



Source: airmilescalculator.com

Figure 4.7 Distances from KEF to JFK and FRA

The medium route starts in Frankfurt, Germany on board a Boeing 757-200. It travels 2,402 km to its destination point in Keflavik.
Additionally, all of those who arrive via flight usually have to get themselves to the capital. In this analysis it is assumed that the medium consumption tourist chooses the airport bus, the Flybus (chosen by random sample) in this case which is a scheduled coach operated by *Reykjavik Excursions* (RE) transporting both tourists and Icelanders to and from Keflavik airport (re.is/flybus), a 51 km distance (here.com). This is mainly done in order to incorporate the use of buses by this tourist type. The coach itself used for this analysis was also chosen by a random sample of RE´s car park and is a 2011-2013 model VDL Futura with 55 passenger capacity (+2: driver and guide). Its fuel consumption standard is a Euro V with the estimated summer fuel consumption of 26.5 l/100km. The fuel consumption is

actual consumption and was obtained from Reykjavik Excursions (Jóhanna Hreiðarsdóttir, HR-manager, personal communications, January 27th 2014). Since RE is one of the largest day-tour operators in Iceland, this bus is used as a basis for other coaches in this research.

The most preferred transportation mode among those who consider themselves in the medium income category is rental cars (45%). Other popular transportation choices were scheduled buses by 38.2% and tour buses by 37.1%. This data also fits nicely when the answers from flight-passengers are compared, with the majority of them (47.8%) preferring rental cars and 38.1% prefering schedule buses.

In the medium consumption scenario, the tourist mostly uses a medium/regular sized rental car to travel around Iceland. This tourist mostly follows ring road number 1 (see Figure 4.5) anti-clockwise from Reykjavik, with the exception that he drives east to Þingvellir through Mosfellsheiði, then towards Gullfoss and Geysir where he heads south until reaching route number 1 once again. From there he continues his eastbound journey. This route was chosen since 72.4% of those who consider themselves to have medium income and 71% of those who arrived by plane visited the Golden Circle.

The hypothetical medium scenario route (see Figure 4.8) also includes a visit to Húsavík (bubble 5) in the north and Stykkishólmur (bubble 6) on the Snæfellsnes peninsula, since 34.8% visited Húsavík and 35.2% visited Snæfellsnes National Park, which is at the tip of the peninsula.

Figure 4.8 Medium consumption tourists route around Iceland.

According to Here.com, the distance travelled by the medium consumption tourist in its rental car for eight (7.7) days is 1,544 km.

At the time these words are written, there are 140 car rentals operating in Iceland with 11,629 registered vehicles as rentals (SAF 2013), while they were only 7,888 in number at the beginning of 2012 (Anna M. Björnsdóttir, The Road Traffic Directorate - personal communication, March 27th 2014). The representatives of two fully authorized car rentals in Iceland, who have large market share, were contacted during the data acquisition process. They were Benedikt Helgason, sales manager with *Thrifty* and Jón Gestur Helgason with *Höldur Car Rental* (personal communication, January 21st 2014). They both agreed that the most popular rental cars in Iceland are regular sized passenger cars where the average passenger number is 2-3 persons per car, but neither of them had any statistical data to support that – it was mostly an impression built on professional experience. Therefore, and supported by the results on the question about travel companions in the ITB-survey, it is assumed that there are two persons (a couple) in each rental car for the medium and high consumption scenarios.

Thrifty claimed the most popular car in 2011 would have been the Ford Fiesta, diesel powered, 1.6 l engine size, manual transmission (Egill Helgason – general manager, personal communication, March 27th 2014). They also claimed that their average summer rental period was 7.7 days, ranging from 6.1-8.5 days (May to August 2012), and according to the odometers of their cars the most typical distance travelled was 2,000-2,500 km. If the median, 2,250 km is divided by 7.7 days, the result is 292 km per day – which is quite high, considering estimates from 2010 of 200-250 km average driving distance (Steingrímur Birgisson 2010).

This high number in daily travel distance can perhaps be linked to people´s spontaneous decision to go off the main road and follow a detour, maybe to a glacier, a mountain or a volcanic ash beach. Therefore, to incorporate the various off-road sidetracks, the data from a professional car rental company was trusted and decided to use the lower number of 2,000 km as a reference, a value approximately 30% more than the calculated route of 1,544 km. It was concluded that it would be justifiable to add 30% to all the calculated routes, i.e. for medium and high consumption scenarios in domestic transportation. Therefore the medium scenario route becomes 2,007 km long (1,544*1.3).

4.2.3 High transportation choices

The high consumption route starts in New York, USA on board a Boeing 757-200. It travels 4,168 km to its destination point in Keflavik (airmilescalculator.com). In this analysis it is assumed that the high consumption tourist chooses a taxi to travel from the airport to his hotel in Reykjavik but the airport bus on its way back. The specific taxi used in this analysis was chosen by a random sample since there is no special way of knowing what kind of passenger car will be next in line at the airport. Nonetheless, since taxis come in all different sizes and shapes, it is assumed that the high consumption tourist travelling with only his wife gets a regular sized passenger car (4+1). According to the Icelandic Road Traffic Directorate (2014), the taxi with the private licence plate number PU791 is a Mercedes Benz – E, 2005 model, with the emission factor per kilometre of 179 gr CO_2.

As previously mentioned, the most preferred transportation mode among those who consider themselves to be in the high income category is rental cars (47.1%) Other popular transportation choices mentioned by this income type in the ITB-survey were tour buses (40.7%) and schedule buses (28.2%).

The route starts in New York, USA, but once in Iceland the high consumption tourist mostly uses a 4x4 rental car to travel around Iceland. It is assumed that the high consumption tourist selects a comfortable 4x4 jeep. Based on the long-term experience of Thrifty´s operations manager (Bergur F. Maríuson, personal communication March 29th 2014), the Ford Explorer would be the most likely candidate in their collection to be chosen by a high consumption tourist. The Explorer has 5 seats, automatic transmission and uses regular petrol.

This tourist travels a similar route as medium consumption tourist with the exception of Snæfellsnes-peninsula due to fewer overall days. This route was chosen since it encompasses all major towns in relevant regions visited by this income type. Perhaps it may be referred to as Iceland´s "express route", remembering the words of Tryggvi Marinósson from Hamrar.

The route through the Golden Circle was chosen for the same reason as per the medium consumption scenario.

Figure 4.9 High consumption tourists route around Iceland

The route starts and ends in Reykjavik. Its duration is five days and about 1,360 km long, according to *Here.com* (see Figure 4.9). However, after adding the 30% for various detours, it sums up to 1,768 km, thus making it the shortest route taken of all three tourist types.

4.3 Accommodation

For analytical reasons, the Icelandic Tourism Board (ITB) has segmented the country into eight different parts (see Figure 4.10). In the ITB-survey from 2011 tourists were asked which parts of the country they visited and how many nights they stayed in each part. This information proved to be valuable since this study assumes that all three tourist types travelling around the country decide on different accommodation options for various durations. The results in the ITB-survey are used as an indication of how many nights are spent in each region but scaled to individual trip duration, i.e. 7, 11 or 16 nights in Iceland.

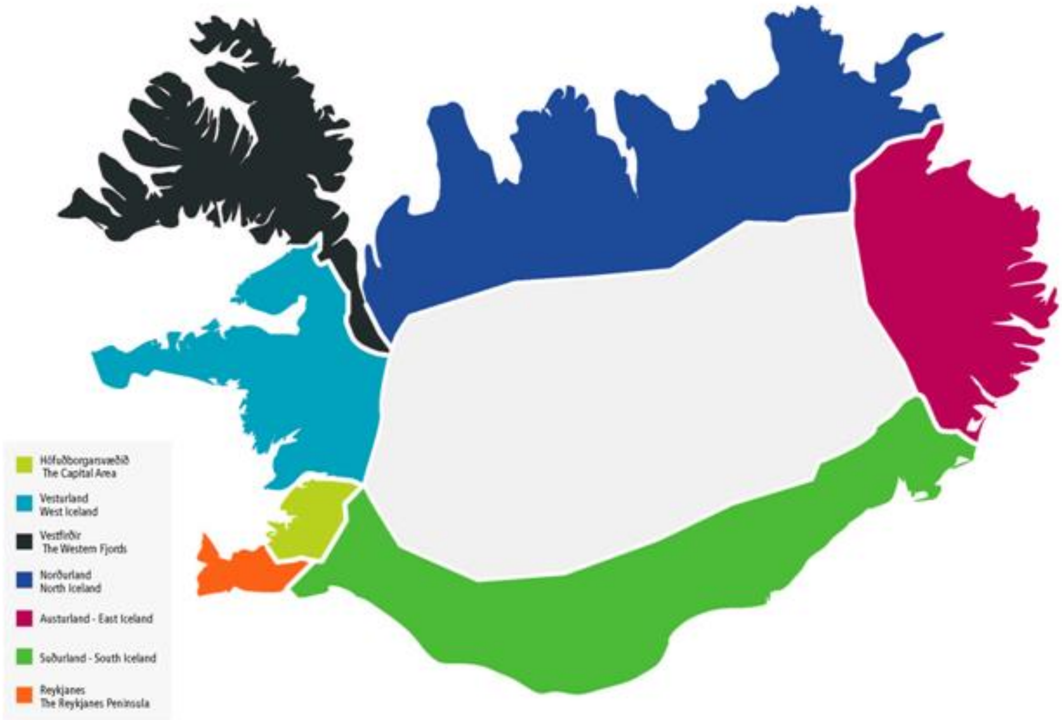


Figure 4.10 Icelandic Tourist Board segmentation of Iceland – 8 Regions

Table 4.3 further describes the regions that were at some point visited by those who answered the ITB-survey. Those who stayed overnight in each region were asked to indicate the number of nights. The ratio of overnight stays is also depicted along with the overall average night spent in each region. The small numbers in brackets indicate the deviation range (+/-) from the average.

The majority of respondents visited the capital area (92.7%). Of the total who decided to spend the night there, most of them (30.7%) preferred to stay 3-4 nights. Nonetheless, the total average nights stayed was 4.5 nights.

The region least visited was the Reykjanes peninsula, where 15% of respondents came and most of those who stayed there (87.4%) only spent 1-2 nights there. The average nights spent there was 1.7.

Table 4.3 Nights spent in all regions of Iceland – ITB-respondents

	Those who visited the …	Most preferred nights stayed	Ratio of total who stayed	Average night (+/-)
Capital area	92.7%	3-4 nights	30.7%	4.5 (0.4)
West Iceland	29.9%	1-2 nights	73.1%	2.3 (0.2)
Western Fjords	12.3%	1-2 nights	52.4%	3.1 (0.3)
North Iceland	40.1%	3-4 nights	44%	3.6 (0.2)
East Iceland	29.6%	1-2 nights	75.2%	2.5 (0.3)
South Iceland	49.4%	1-2 nights	38.7%	3.7 (0.3)
Reykjanes Peninsula	15.1%	1-2 nights	87.4%	1.7 (0.3)
Highlands	18.1%	1-2 nights	49.1%	3.4 (0.3)

It is not sufficient to observe the regions where the tourists stayed. It is also important to know the type of accommodation, since it is the most important factor in the CF analysis for accommodation. In Table 4.4 the preferred accommodation choices of all who answered the ITB-survey are stated.

Table 4.4 Accommodation choices and duration of stay among ITB-respondents

	Those who stayed	Most preferred nights	Preferred by …	Average night (+/-)
Hotels / Guesthouses	77.2%	5-7 nights	31.6%	5.7 (0.2)
Farm holiday accommodation	11.2%	1-2 nights	46.6%	4.6 (1.2)
Hostels / lodges in wilderness and similar	19.4%	1-2 nights	35.1%	5.5 (1.4)
Summer cottages / guest residence and similar	11.3%	1-2 nights	36.3%	6.2 (1.3)
Camping/Caravan sites	19.1%	More than 15 nights	22.7%	10.6 (0.8)
Friends / relatives (unpaid accommodation)	7.1%	5-7 nights	25.5%	8.3 (1.5)
Other types of accommodation	9.1%	1-2 nights	28%	9.5 (2.4)

Most respondents decided to stay at a hotel or guesthouse (77.2%). Most of those who stayed overnight (31.6%) preferred 5-7 nights and the overall average night was 5.7.
Farm holiday accommodations, *hostels/lodges in wilderness and similar*, and *summer cottages/guest residence and similar* where chosen by 11-19% of respondents and most (35-47%) preferred 1-2 nights. The total average nights stayed varied from 4.6-6.2 nights. *Camping/caravan sites* were chosen by 19.1% of respondents where most (22.7%) chose to stay more than 15 nights, while the average was 10.6 nights.

Friends / relatives (unpaid accommodation) and *other types of accommodation* was least chosen, with only 7.1% and 9.1% respectively.

Due to the risk of double counting, accommodation with friends and relatives and other types of accommodation is not included in the individual CF calculations for accommodation. The emissions from Icelandic homes belongs to another CF arena and were therefore deemed outside the boundaries of this study.

Furthermore, the three categories where most respondents only preferred 1-2 nights were combined into one category in the form of hostels/lodges (see Figure 4.11).

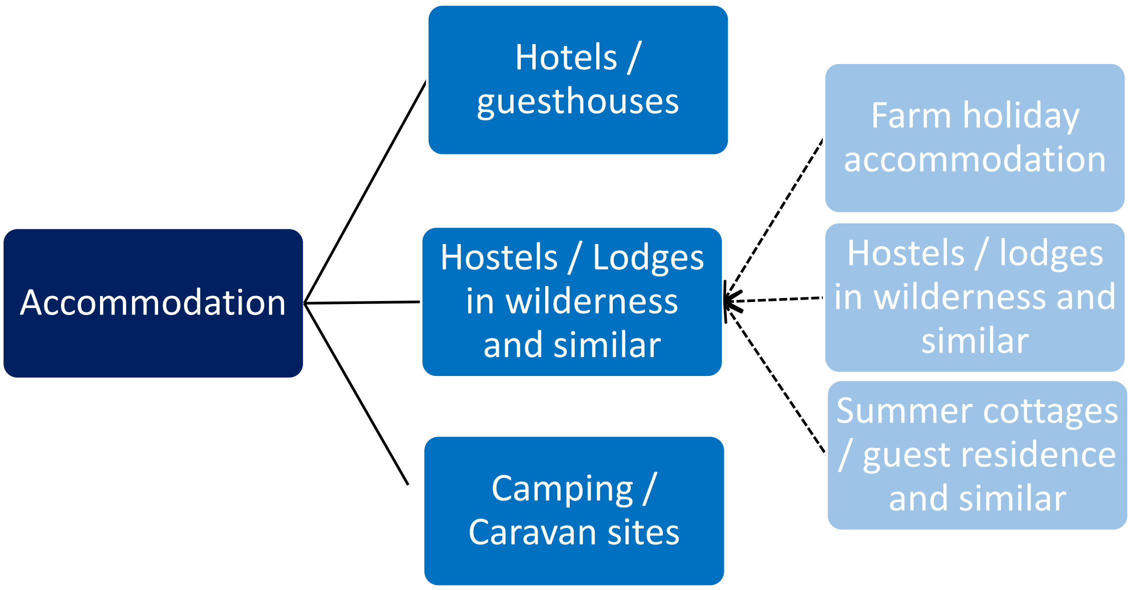


Figure 4.11 Three main accommodation categories

The reason for this merger is partly due to the fact that no reliable data was found on farm holiday accommodation, lodges in wilderness and summer cottages, guest residences and similar accommodation. There was however good data found on hostels, and since most can probably agree that all three accommodation categories are not considered high end or luxury accommodation, they were merged together.

The information in Tables 4.3 and 4.4 is useful when it comes to building the hypothetical route for each tourist type around Iceland. It is however not sufficient on its own for the CF analysis. In the attempt to reflect reality in the hypothetical route for each consumption type (i.e. 7 nights for high, 11 for medium and 16 for low), the average night spent in each part according to the ITB-survey is extrapolated and scaled to fit each trip duration with the assistance of equation one, as seen below.

The same equation is also used to scale the duration in relevant accommodation types.

$$AVXn = \left(\frac{AVn1...}{\sum AVn} \right) * F \qquad \text{(eq.1)}$$

Where:

AVXn: The scaled night for relevant region or accommodation type
AVn1: The average nights in individual region or accommodation type
$\sum AVn$: The sum of all average nights in all regions or accommodation types
F: The frame that the scaling shall apply for, i.e. 7, 11 or 16 night frame

Afterwards, the numbers are rounded off and a realistic picture of accommodation choices is revealed for each tourist type categorized by income (seen in Tables 4.5 through 4.10) and derived from actual data.

Next, an analysis and application of equation one takes place. Firstly this occurs with low consumption choices in mind, but is followed by medium and high consumption choices.

4.3.1 Low accommodation choices - Backpacker

The low consumption tourist visited all of the relevant regions analysed here, i.e five out of eight. In Table 4.5 one can see how many nights were spent in each region after they have been processed using equation one and with a 16 night timeframe in mind. In correlation with the majority of those who answered the ITB-survey, most respondents spent most nights in the capital area where they chose to stay 5-7 nights, while the total average was 7.7 nights. However, after the scaling process of equation one ((7.7/25.3)*16), the outcome is revealed to be 5 (4.9) nights. Only two nights are spent in east Iceland but three nights are spent in south, north and west Iceland.

Table 4.5 Nights spent by low income tourists in each region

Region	Most often chosen by low income tourists	Average nights in region by low income	Eq.1. Average nights divided by sum of average nights *16	Adjusted for low scenario
Capital area	5-7 nights	7.7	4.9	5
West Iceland	1-2 nights	5.4	3.4	3
North Iceland	1-2 nights	4.9	3.1	3
East Iceland	1-2 nights	3.7	2.3	2
South Iceland	3-4 nights	3.6	2.3	2+1
Total:		25.3		16

There is one anomaly to be mentioned in the adjustment for south Iceland. All the calculations and adjustments fitted fairly well with the number of nights most often preferred by this income category in each country part, except in south Iceland. Therefore, since there was an extra night available due to the decimal cut off, that extra night was added to south

Iceland, which therefore concluded the 16 night round trip and fitted well with the most often chosen option by this income type.
The ships' functionalities during its transporation to and from Iceland must also be considered, which is four nights both ways, but will be added to the on-land duration when it comes to calculating the CO_2 emissions per day from this tourist type.

The most preferred accommodation choices among those who considered themselves to receive low income in their home country can be seen in Table 4.6.

Table 4.6 Accommodation choices among low income tourists

Low income Accommodation choices	Most often chosen by low income tourists	Ratio of those with low income	Average nights (+/-)	Eq.1. Average nights divided by sum of average nights *16	Results from Eq.1 for accommodation type	Adjusted
Hotels/ Guesthouses	5-7 nights	35.1%	4.5 (0.7)	1.7	2	2
Farm holiday accommodation	1-2 nights	58.9%	3.3 (2.2)	1.2	1	
Hostels/lodges in wilderness and similar	1-2 nights	39.5%	5.7 (1.9)	2.1	2	(1 + 2 + 2) = 5
Summer cottages/guest residence and similar	1-2 nights	28.7%	18.5 (26.1)	6.9	7 (-5)= 2	
Camping/ Caravan sites	More than 15 nights	31.4%	11.1 (3.0)	4.1	4 (+5) = 9	9
Total:			43.1			16

Most low income tourists usually preferred to spend 5-7 nights in hotels/guesthouses (35%). The total average nights was 4.5, but after the process with equation one ((4.5/43.1)*16) the outcome was 2 (1.7) nights. As previously mentioned, three accommodation types were merged into one – hostels/lodges – where the outcome was five nights and nine nights in camping/caravan sites.
In the case of summer cottages/guest residence and similar, there was a quite a large deviation from the average (+/- 26.1) created by only 13 respondents in this case. In an attempt to give balance to the accommodation choices of low consumption, it was decided to follow the higher number in the most often chosen category, or 2 nights. The five days withdrawn from the summer cottages/guest residence and similar were added to camping/caravan sites in order to level out that abnormality, since the largest single majority (see Table 4.4) of those who answered the question overall, or 22.7%, preferred to stay more than fifteen nights in that type of accommodation.

This approach is unconventional and the researcher certainly acknowledges that. Nevertheless, this was considered to be the most appropriate way of retrieving useable information from this secondary set of data for the analysis intended in this research.

4.3.2 Medium accommodation choices – The average tourist

The medium consumption tourist also visited all of the relevant regions analysed. The medium consumption accommodation choices can be seen in Table 4.7, i.e how many nights were spent in each region after they have been processed by equation one and with an 11 night timeframe in mind. Most people with medium income preferred the capital area, where the total average duration was 4.2 nights. After the scaling process of equation one ((4.3/16.2)*11), the outcome is three nights (2.9). West Iceland was the least popular region among this income type, with only 2.1 average nights which is reduced to only one night after the scaling process.

Table 4.7 Nights spent by average income tourists in each region

Region	Most often chosen by medium income tourists	Average nights in region by medium income	Eq.1. Average nights divided by sum of average nights *11	Adjusted for medium scenario
Capital area	3-4 nights	4.3	2.9	3
West Iceland	1-2 nights	2.1	1.4	1
North Iceland	3-4 nights	3.5	2.4	2
East Iceland	1-2 nights	2.6	1.8	2
South Iceland	1-2 nights	3.7	2.5	3
Total:		16.2		11

The outcome from Table 4.7 fits considerably well when compared to the most often chosen and/or average number of nights spent by most people in this income category in each region.

The most preferred accommodation choices among those who considered themselves to receive medium income in their home country can be seen in Table 4.8.

Table 4.8 Accommodation choices among medium income tourists

Medium income Accommodation choices	Most often chosen by medium income tourists	Ratio of those with medium income	Average nights (+/-)	Eq.1. Average nights divided by sum of average nights *11	Results from Eq.1 for accommodation type	Adjusted
Hotels/ Guesthouses	5-7 nights	31.0%	5.7 (0.5)	1.9	2	2
Farm holiday accommodation	1-2 nights	47.8%	5.8 (3.2)	2.0	2	
Hostels/ lodges in wilderness and similar	1-2 nights	35.0%	4.5 (0.5)	1.6	1.6	5
Summer cottages/ guest residence and similar	1-2 nights	40.1%	5 (0.9)	1.7	1.7	
Camping/ Caravan sites	More than 15 nights	25.0%	10.9 (1.2)	3.8	3.8	4
Total:			31.9			11

Medium income tourists usually preferred to spend 5-7 nights in hotels/guesthouses (31%). The total average nights was 5.7, but after the scaling process of equation one ((5.7/31.9)*11) the outcome is two (1.9) nights. The merged accommodation category of hostels/lodges takes five nights while camping/caravan sites take four nights out of the 11 night total.

Next, the accommodation choices of the high consumption tourist are analysed.

4.3.3 High accommodation choices – Quick and easy

This tourist visited all of the relevant regions. In Table 4.9 one can see how many nights were spent in each region after they have been processed by equation one and with a seven night timeframe in mind.

Most people with high income also preferred the capital area where the total average nights spent was 3.9. After the scaling process of equation one ((3.9/14.8)*7), the outcome is two nights (1.8). The least popular area among this income group was east Iceland with one night (0.8), followed by west Iceland with one night (1.0) also. Two nights (1.6) were spent in south Iceland while only one night (1.6) was spent in north Iceland. According to normal calculation standards, the decimals should have been rounded up for the north Iceland results, but it was decided to round this number down because of higher deviation (+/- 0.5 against +/-0.4 in South Iceland) and relatively fewer people that visited North

Iceland (40.1%) compared to South Iceland (49.4%). This also ensured that the seven night timeframe was respected, or 6.9 nights with all decimals accounted for.

Table 4.9 Nights spent by high income tourists in each region

Region	Most often chosen by high income tourists	Average nights in region by high income	Eq.1. Average nights divided by sum of average nights *7	Adjusted for high scenario
Capital area	3-4 nights	3.9	1.8	2
West Iceland	1-2 nights	2.2	1.0	1
North Iceland	3-4 nights	3.3	1.6	(2-1)=1
East Iceland	1-2 nights	2	0.9	1
South Iceland	3-4 nights	3.4	1.6	2
Total:		14.8		7

The most preferred accommodation choices among those who considered themselves to receive high income in their home country can be seen in Table 4.10.

Table 4.10 Accommodation choices among high income tourists

High income Accommodation choices	Most often chosen by high income tourists	Ratio of those with high income	Average nights (+/-)	Eq.1. Average nights divided by sum of average nights *7	Results from Eq.1 for accommodation type	Adjusted
Hotels/ Guesthouses	3-4 nights	27.4%	5.9 (0.6)	1.5	1	(1+1)=2
Farm holiday accommodation	3-4 nights	39.3%	3.8 (1.3)	0.9	1	1
Hostels / lodges in wilderness and similar	3-4 nights	35.3%	4.5 (1.8)	1.1	1	1
Summer cottages / guest residence and similar	3-4 nights	37.8%	5.1 (2.0)	1.3	1	1
Camping / Caravan sites	1-2 nights	23.7%	8.7 (3.1)	2.2	2	2
		Total:	28			7

High income tourists usually preferred to spend 3-4 nights in all accommodation choices except in camping/caravan sites where they only stayed 1-2 nights. The total average nights per accommodation type ranged from 3.8 to 8.7 nights, but after the scaling process of equation one (i.e. (3.8/28)*7) the outcome is usually one night in all accommodation types except camping/caravan sites where the number was two nights. In hotels/guesthouses the adjusted number was rounded up to two nights because the capital area was the most popular region among this income group, and since data is unavailable it is assumed that this tourist type prefers hotels in the capital area. Therefore, the decimal cut-offs from the other accommodation types were added to hotels/guesthouses and thus, once again, maintaining the seven night timeframe.

4.4 Attractions and activities

Activity choices between the three tourist types are analysed, but the general conclusion from the report is that most people (32.7%) undertook recreational activities connected with nature 1-2 times during their stay. Nearly 25% chose not to do anything, while 18.7% went 3-4 times.

In the ITB-survey, tourists were given a checklist of 15 different activities to indicate if they had paid for it during their stay. These activities have their individual carbon footprint, but only the most popular activities among each consumption group were incorporated into this carbon footprint analysis since this proved to be a very difficult part to calculate and/or estimate due to overall similar behaviour and a lack of data.

When the activities and attractions sites are considered for all income types, the tourist choices can be seen in Table 4.11 where it becomes obvious that all tourist choices are very similar to each other. The most popular attractions sites and activities for all income types are *geothermal swimming pools/nature baths*, where 65.2% of all high income tourists and about 71.2% of both low and medium income tourists attended during their stay. The second most popular activity was *museums/exhibitions*, where 41-45% of all income types attended. *Guided sight seeing tours* are more popular among high (40%) and medium (36.4%) income types, while *whale watching* is more popular among medium income types (35.3%). Strangely, *spas and wellness* is something that low income tourists indulge in more than others (26%) as well as *horse riding tours* (28.9%). *Boat trips other than whale watching* is more popular among medium income tourists (17.1%) and the same goes for *glacier/snowmobile trips* (15.3%).

Table 4.11 Attraction sites and activities chosen by all tourist types

Activities	Low income	Medium income	High income
Geothermal swimming pools / nature baths	70.2%	71.2%	65.2%
Museums / Exhibitions	42.2%	44.6%	41.7%
Guided sight-seeing tours	19.5%	36.4%	40.0%
Whale watching*	27.7%	35.3%	27.2%
Spas / Wellness	26.0%	23.4%	19.4%
Horse riding*	28.9%	15.7%	17.9%
Boat trip (other than whale watching)*	16.0%	17.1%	12.2%
Glacier / Snowmobile trip*	9.1%	15.3%	13.6%
Guided hiking / mountain trips*	10.0%	15.8%	13.5%
Other cultural events (Theatre, concerts, etc.)	8.7%	8.4%	8.0%
Festival, local event	11.9%	6.3%	1.8%

* Recreational activities connected with nature.

In addition to the activities in Table 4.11, tourists could check *river rafting/kayaking*, *cycling tours*, *golf*, *other* or *none of the above*. However, since there were so few who participated in that kind of activity (from 9.7% for *other activities/attraction sites* to only 0.6% for *golf*), these categories were excluded.

Next, the individual tourist choices in activities and attraction sites will be analysed.

4.4.1 Low activity choices

Geothermal swimming pools/nature baths are very popular, but also museums and exhibitions where 70.2% and 42.2% of low income tourists paid for those respective activities. However, when participants were asked how often they undertook recreational activites connected with nature (indicated with * in the list), the majority of those receiving low income (40.3%) said they only undertook it 1-2 times, while 24.3% never participated in any such activities. This correlates with the answers from those who travelled with Norröna – 38.9% went 1-2 times, while 25.4% claimed they never did anything. Most of the same income category, or 44.6%, claimed they had gone 1-2 times to a museum, exhibitions, concerts, theatres or other cultural events. A total of 33.8% said they never went to any such activities.

4.4.2 Medium activity choices

In a similar vein to the low consumption interests, geothermal swimming pools / nature baths are very popular as well as museums and exhibitions where 71.2% and 44.6% of medium income tourists paid for those two respective activities. Other popular activities are guided sightseeing tours (36.4%) and whale watching (35.3%).

The majority of those receiving medium income (31.5%) claim they only undertook recreational activites connected with nature 1-2 times, while 24.7% never participated in any such activities and 19.6% claimed they went 3-4 times. When the answers from those who arrived by plane are compared, the majority (32.3%) also only went 1-2 times. Most of the same income category, or 42.9%, claimed to have gone 1-2 times to a museum, exhibitions, concerts, theatres or other cultural events. A total of 31.6% said they never took part in any of these activities and 17.9% visited 3-4 times.

Again, as was the case for low income tourists, it was difficult to pinpoint which 1-2 from the overall list of paid activities to calculate the CF for because these tourist choices are very similar to the decisions made by low consumption tourists.

4.4.3 High activity choices

As was the case for the other two tourist types, geothermal swimming pools/nature baths are very popular as well as museums and exhibitions, where 66.2% and 41.7% of high income tourists paid for those respective activities. This consumption type chose guided sightseeing tours relatively the most (40%), but was as interested in whale watching as the low consumption tourists (27.2%).

The majority of those receiving high income (39.9%) claim they only undertook recreational activites connected with nature 1-2 times, while 22% never participated in any such activities and 16.9% claimed they went 3-4 times.

Most of those who received high income (36.1%) claimed they went 1-2 times to museums, exhibitions, concerts, theatres or other cultural events. A total of 39.8% said they never went to any such activities and 12.5% went 3-4 times.

The same problem arises here as before. It is difficult to pinpoint which 1-2 from the overall list of paid activities to calculate the CF for.

4.4.4 Chosen activities of all tourist types

All tourist types claim they only paid for 1-2 attractions/activites on average during their stay in Iceland. Consequently, for the purposes of this analysis, a different approach had to be taken to prescribe certain activities to each tourist type since they all chose the same or very similar activities/attraction sites. Thus, Market and Media Research (MMR) – the company responsible for conducting the ITB-survey – was contacted and asked to find the exact answers from tourists that fitted the profiles used in this study and fitted into the expenditure frame. This helped track down those who had spent similar amounts on admission fees and sightseeing tours, as the overall average spent by their fellow tourist types. This information was provided. Afterwards, one individual was randomly chosen in low, medium and high income category (thus a total of three tourists) and their specific activity/attraction choices were listed (see Table 4.12). The CO_2 emissions were then calculated based on their individual choices and assigned to the appropriate scenario.

Table 4.12 Chosen activities of all three tourist types

Activities	Low	Medium	High
Geothermal swimming pools / nature baths		X	X
Museums / Exhibitions	X	X	X
Guided sight-seeing tours			
Whale watching	X	X	X
Spas / Wellness	(X)	-	-
Horse riding	-	-	-
Boat trip (other than whale watching)			
Glacier / Snowmobile trip			X
Guided hiking / mountain trips			
Other cultural events (Theatre, concerts, etc.)			

All income types chose museum/exhibitions. None chose guided sightseeing tours and all chose whale watching. Spas and wellness was excluded while guided hiking/mountain trips were only chosen by high income tourists.

As previously stated, different decisions of tourists will reflect a different carbon footprint.

Next, the various emission factors will be described in order to calculate the CF of each tourist type.

4.5 Emission factors and energy use

The emission factors come from several different sources, e.g. from various hotels, guesthouses, camping grounds, tour operators, museums, travel agencies, airports etc. People were first contacted through e-mails which was usually followed up with a phonecall. On a few occasions business representatives were met and their operations matters discussed in more detail. Most operators in the accommodation sector were unwilling to specify their visitor numbers and/or visitor nights (explained later) due to competitive reasons. Those who did provide the information, made it clear that visitor nights could not be mentioned on these pages. Nonetheless, the limited emission factors that were obtained during this tedious data acquisition process are valid and will be used since they provide country specific data. The emission factors were regularly checked and compared with other emission factors derived from similar research reports or guidelines.

In accordance with the previous order of categories, first the transportation will be analysed, then the accommodation and finally attractions and activity choices.

The bottom-up approach is also used in this analysis. The approach revolves around estimating emissions of different transportation modes based on their individual activities, for example distances or known fuel consumption. For comparison, a top-down approach would use financial data to calculate the quantity of fuel consumption, which could then indicate the emissions involved via its combustion (Howitt et al 2010).

Next, the emissions factors for transportation will be explained.

4.5.1 Transportation

The GHG Protocol (2005) suggests two main approaches to calculate CO_2 emissions from mobile sources. The differences depends mainly on the data availability.
The methods are:

- Distance-based methodology:
  Where emissions are calculated by using distance based emission factors to calculate emissions.

- Fuel-based methodology:
  Where known fuel consumption is multiplied by an assigned CO_2 emission factor for the fuel type used.

In the results section both methods are applied, since data was interchangeable between transportation methods. Generally, the fuel-based methodology is preferred since it is considered more accurate than the distance-based method. Furthermore, where country specific data was available, that was usually used for calculations.
The transportation modes evaluated in this analysis consisted of the three main modes, i.e. air, sea, and road transport. Note that in the results chapter (nr. 5) all paying passengers on board the airplanes and Smyril Line´s ferry will be made accountable for their individual emissions during that particular journey, irrespective of the possibility that some passengers will continue on with another flight to a subsequent destination or disembark somewhere on the way. Issued load factors for these particular journeys, given from relevant authorities and/or employees, are fully trusted and applied both ways in this analysis.

Airplane – Boeing 757-200

The *International Civil Aviation Organisation* (ICAO) is a specialized agency under the United Nations framework created in 1944 at the Convention on International Civil Aviation. ICAO's role is to develop international *Standards and Recommended Practices* (SARP´s) in collaboration with its 191 signatory states and relevant stakeholders in the aviation industry (ICAO 2011a).
ICAO has developed a user friendly Carbon Emissions Calculator on their internet webpage (2011b) where people can simply chose their pair airports (departure/arrival) and the calculator uses global averages in fuel consumption, freight load, quantity of seats etc., to indicate the environmental cost of that particular journey, measured in CO_2 kg per person.

For more detailed weight, the calculations in this analysis were done manually for each flight in the resulting section. Equation two, issued by ICAO (2011c), calculates direct CO_2 emissions per revenue passenger (pax) from aircrafts:

$$CO2\,perPax = EF * \left(\frac{F * PFf}{S * PLf} \right) \qquad \text{(eq.2)}$$

Where:

CO_2 per Pax: is the estimated quantity of emissions, measured in kg CO_2, per revenue passenger

EF: is the CO_2 emission factor from the burning of one tonne of aviation fuel

F: is the total fuel used while flying the relevant distance – this information is derived from ICAO (2011c) for the relevant type of aircraft

PFf: is the *pax-to-freight* factor – the typical ratio of freight for this route

S: is the seats available on the flight in question (crew not included)

PLf: is the passenger load factor – the typical ratio between passengers transported and number of seats available in the flights in question

Airlines like the Emirates and British Airways regularly calculate the CO_2 emissions per kilometre per revenue passenger (CO_2/pkm). In this case it can be done using equation 3 (Howitt et al 2010 and AEA 2014), and will on rare occasions be applied in this analysis:

$$CO2\,pkm = \frac{CO2}{(PAX * D)} \qquad \text{(eq.3)}$$

Where:

CO_2 pkm: is the CO_2 emission per passenger kilometre, indicated in grammes or kilogrammes

CO_2: is the total quantity of CO_2 emissions released during a particular journey, indicated in grammes or kilogrammes

D: is the total distance travelled during a particular journey, indicated in kilometres.

Pax: is the total number of paying customers

Some guidelines suggest that those passengers who fly on first or business class deserve an uplift of 15-60%. This is because these seats offer more space and legroom at the cost of fewer seats on board the aircraft (Torchbox 2008). However, in this analysis it is assumed that the aircraft is homogeneous and all seats are the same, i.e. economy class. There are two reasons behind this: firstly, because the number of first class seats can vary quite extensively between airliners; and secondly, it was to make the calculations fairly simple.

Several sources of information need to be clear for each flight in question for the medium and high consumption scenarios. Delta Airlines uses Boeing 757-200, with the seating arrangement (*S*) of 181 seats (Delta 2014). The Icelandic airliner, Icelandair, which also flies to both Frankfurt and New York on a Boeing 757-200, has only two seats more in its seating capacity (Icelandair n.d.).

For medium consumption scenario, the typical fuel consumption for this type of aircraft flying this distance (*F*) is 10,443 t and the typical ratio of freight (*PFf)* for this route (North Atlantic route) according to ICAO is 98.12%. ICAO also issues the typical ratio

between passengers transported and number of seats available in the flight (*PLf*), which is 83.55% on average. The emission factor (*EF)* for aviation fuel is 3.157 (ICAO 2011b).
For high consumption scenario, the The Boeing 757-200 with 181 seats (*S*) is also used for the flight from North-America´s John F. Kennedy (JFK) airport in New York to Keflavik Airport. The following is the JFK-KEF flight information, which is also used for the return flight:

EF:	3.157
F:	17,223.7 t
PFf:	98.12%
S:	181 (Delta´s Boeing 757-200)
PLf:	81.2% (average for international Delta flights)

Ships and boats – Smyril Line ferry; Norröna

The emissions from ships can be calculated using a simple equation (4) issued by the IPCC (2006).

$$\text{Emissions} = \sum \text{FC} * \text{EF} \qquad \text{(eq.4)}$$

Where:

Emission:	is the total CO_2 emission for that particular journey measured, indicated in grammes or kilogrammes
∑ *FC:*	is the total fuel consumption.
EF:	is the emission factor for the specific fuel type burnt

With the focus here on Smyril Line ferry Norröna, its former captain claims that the ship burns 124 t of fuel during its journey from Hirtshals to Seydisfjordur via Thorshavn (Jógvan í Dávastovu, personal communication, January 27th 2014). Included in this number are all the ship's functionalities, i.e. its hotel/accommodation function for four nights during its 1,921 km long voyage from Denmark to Iceland via the Faroe Islands, (Smyril Line n.d.,b).

According to the IMO (2005), the CO_2 emission factor for HFO is 3.114 t CO_2 per t of fuel. The ship can take 1,482 passengers, but in the summer Norröna usually has a load factor of nearly 75% (Jógvan í Dávastovu, personal communication, January 27th 2014). Information on load factor is not necessary for equation 4 but certainly helpful when it comes to estimate CO_2 weight per passenger. Therefore, it can be estimated that 1,112 passengers (1,482*0.75) were onboard Norröna heading towards Seydisfjordur for the low scenario.

In order to include the passengers and quantify their emissions per passenger kilometre, equation 3 can also be used for ships and boats but will not be necessary for this analysis.

Road transport – Backpacker buses

Unfortunately there was not much data to be found on buses/coaches in Iceland. According to the Road Traffic Directorate there were 1,972 registered buses and coaches (long-distance) in Iceland in 2011. Roughly 94% (1,850 in number) were diesel powered opposed to 117 petrol powered, and a little less than half of the fleet (48%) is based in the capital area

(Road Traffic Directorate n.d.,b). The current average age of the fleet is 15.9 years according to the Icelandic Transport Authority (Icelandic Transportation Authority, in Ingveldur Geirsdóttir 2014), where most of the older coaches serve as school buses, both in urban and rural areas according to Hallgrímur Lárusson, CEO of Snæland Grímsson coach company (in Ingveldur Geirsdóttir 2014).
However, the fleet is slowly being renewed and many of the day-tour companies have a considerably more modern fleet. For example, the Reykjavik Excursions fleet has an average age of 10 years, with various sized vehicles from 12-73 seats (Sigríður Ásta Hallgrímsdóttir, office manager of RE - personal communication, July 17th 2014).

According to Óskar Stefánsson (2011), the CEO of *Sterna* coach company who operates many of the scheduled tours around Iceland, the largest bus belonging to that part of their service is a 50 seater, but the average number of passengers during a typical journey (in this case from Reykjavik to Akureyri) is 15 persons. This correlates with numbers from Eurostat (2013), where it is stated that in 2011 the average number of passengers on buses in Iceland (coaches were not specified) were 12 and DEFRA (2012) claims the overall global average was 16.2 passengers.

Óskar also mentions fuel consumption of 130 l during the route Reykjavik-Akureyri via Hvammstangi, which, according to the map direction site Here.com, is a route of 398 km. Therefore, the average fuel consumption can be estimated to be 0.33 l per/km (130/398).

Road transport – Rental cars

There is not much information about average CO_2 emissions of rental cars in the European market. According to a Dutch research study on leased cars, the average CO_2 emission of such vehicles in Europe in 2010 was 136 gr/km while in 2012 it dropped to 118 gr/km (VNA 2012).

In the years that followed the economic crisis which struck Iceland late in 2008, there were many concerned about the ageing fleet of Icelandic rental cars (RUV 2012) – applying the argument that an old car is not as safe as a new one. In 2011 the average age of the Icelandic passenger car-fleet had reached a never before seen peak of 11.6 years and continued to age more (Road Traffic Directorate n.d.,a).
Nevertheless, car rentals were responsible for 40% of renewals in the Icelandic car fleet that same year (Viðskiptablaðið 2012). Assuming that car rentals were also responsible for the bulk of car renewals in 2010, the two cars used for the high and medium consumption model were 2010 models. Emission factors for both the Ford Fiesta and Ford Explorer were found to be 98 gr/km and 367 gr/km repectively (Waddington 2009; US Department of Energy 2014).

However, regarding the individual emission factors issued by car manufacturers, DEFRA (2012) claims that many of them do not give the "real-world vehicle performance" (p.29), and thus they suggest an uplift factor of 15% to account for lights, heaters and payload (which usually only includes driver + 25kg), to name a few. A separate research project conducted by the Transport and Environment (T&E) department of Brussels in 2013 reaches a similar conclusion and notes that the fuel economy numbers of most passenger cars bear no relation to reality, concluding that an average of 23% can be added to published numbers from car manufacturers. A representative of Thrifty said that from his experience the increase was closer to 25% (Benedikt Helgason, personal communication, January 28th 2014). Thus, for this analysis, the average between the two published numbers (19%) will be applied as an uplift factor to the relevant emissions factors for most individual vehicles.

Some car manufacturers indicate their emission factors in miles and gallons. In those cases it is assumed that one mile is equal to 1.61 km and one U.S. gallon is equal to 3.785 l (convertit.com 2002).

The GHG Protocol (2005) suggest the following equation to calculate distance based CO_2 emissions from mobile sources:

$$CO2Emissions = D * EF \qquad \text{(eq.5)}$$

Where:

CO2 Emission: or	is the total CO_2 emission for the distance travelled, indicated in grammes kilogrammes
D:	is the total distance travelled during a particular journey, indicated in kilometres or nautical miles.
EF:	is the emission factor for the specific fuel type burnt.

The uplift factor is not automatically included in equation five since it does not apply to all road vehicles used in this analysis. Furthermore, tourist´s use of public transportation modes such as city buses within the capital area and taxis (other than airport-transfer) were not included in this analysis. This is despite the known fact that tourists use them on a daily basis and was due to limited information about actual use patterns. Additionally, no question in the ITB-survey related to this behaviour. It shall be noted that CO_2 calculations for transportation are estimated from paying customers (pax) and do not include necessary and specialised staff directly involved with the vehicle or the tour itself e.g. captains, seamen, pilots, stewards, bus drivers and tour guides.

Next, the emissions factors for accommodation will be explained.

4.5.2 Accommodation

The majority of houses in Iceland (approximately 89%) enjoy the benefits of geothermal heating (Árni Ragnarsson 2010), and the rest are located in cold areas where the heat must be produced with electricity. For the following accommodation section, it is important to have a CO_2 number that goes with the appropriate measurement. Hotels usually measure their performances in terms of *visitor nights*, i.e. the sum of how many nights each guest stayed, so ten visitors for ten nights equates to one hundred visitor nights. Overall, foreign visitors stayed 1.87 million nights in Iceland in 2011 (Icestats 2013b).

For this analysis several accommodation providers all over the country were contacted and asked about their general operations, mostly to do with energy consumption, so that a carbon footprint per visitor night could be established. There were two large hotels in the capital area that replied: a large hostel chain in the capital area and two smaller bed and breakfast accommodations, one in the north and another in the south of Iceland.

Iceland´s National Power Company, Landsvirkjun (LV), was responsible for 73% of Iceland's total electricity production in 2011. The vast majority of its generated energy (96%) was generated from hydropower and 4% from geothermal sources. LV estimates (2011, p.69) that its total GHG emissions for that year were 56,101 t of CO_2-eq, which includes emissions from reservoirs, geothermal production and operations (e.g. fuel, flights, office supplies etc.), and experimental drilling. Landsvirkjun produced 12,485 GWh of electricity in 2011 which equates to 4.49 t CO_2-eq per GWh.
In their annual report from 2011, they break down the GHG types and their origin according to previously mentioned categories. Of the 56,101 t of CO_2-eq emitted, there were 48,722 t specifically assigned to CO_2. Therein, 47,227 t was directly related to the electricity production itself from both geothermal and hydropower – the remaining 1,495 t was due to their own. Consequently, the CO_2 per GWh produced amounts to 3.78 t (Landsvirkjun 2011). This can also be adjusted to 3.78 gr CO_2/kWh (Convertit.com 2002).

The overall division of hydropower and geothermal energy production in Iceland is 73% and 27% respectively (National Energy Authority 2012), while the proportion of hydropower in LV´s portfolio is 96%. Consequently, the weight of 3.78 gr CO_2/kWh is too low to be used as a generalization for the country as a whole, since reservoirs emit far less CO_2 than geothermal power stations (Iceland National Power 2011).
In 2009 the average emission from geothermal power plants in Iceland was estimated to be 50 gr CO_2 per produced kWh, which had reduced by 12% from the year before and further annual decreases were forecasted (Baldvinsson et al 2011).
Reykjavik Energy (2012) estimates that its geothermal power plant at Nesjavellir produced 6 gr CO_2/kWh and the plant at Hellisheiði around 19 gr CO_2/kWh, an average of 12.5 gr CO_2/kWh.
Electrodes circulating Iceland´s power grid aren´t marked with their origin of production. Nevertheless, a representative of Reykjavik Energy stated that approximately 40% of the electricity in the capital area is produced from geothermal power plants (Eiríkur Hjálmarsson - public relations manager, personal communication, November 8th 2012). Therefore, electricity used in the capital area and its vicinity should rightfully be calculated with higher emission factors than where the electricity is produced by hydropower.

On this basis, an attempt was made to give the ordinary kWh in Iceland a CO_2 level without relating it to its place of production or consumption. After carefull analysis of Landsvirkjun's Environmental Report from 2011, the following approach was taken and numbers used (see Table 4.13). In 2011 geothermal power plants produced 39,807 t of CO_2 while hydropower only produced 7,420 t. When the methane gas had been converted into CO_2 equivalents, it accounted for 357 t in geothermal and 6,360 t in hydro. Since CO_2 is the main theme of this research, the proportion of pure CO_2 in this is 99.1% for geothermal and 53.8% for hydropower. These percentages are then used to extract only the CO_2 from the CO_2-eq numbers issued by LV on GWh produced by geothermal and hydropower, 79,848 t CO_2-eq and 1,115 CO_2-eq respectively. That equates to 79,130 t CO_2 for geothermal and 618 t CO_2 for hydropower. Then, with the assistance of convertit.com, the CO_2-level is downscaled to CO_2 gr/kWh, equating to 79 gr/kWh for geothermal and 0.12 gr/kWh for hydropower.
In the light of the overall division of energy production in Iceland (27% geothermal and 73% hydropower), each CO_2 level is scaled according to its particular production output which finally equates to a weighted-average of 21.45 gr CO_2/kWh.

Table 4.13 CO_2 emission from production of average Icelandic kilowatthour

Emissions	Geothermal (power plant)		Hydropower (reservoirs)	
CO_2	39,807 t		7,420 t	
Methane as CO_2-eq	357 t		6,360 t	
Other, as CO_2-eq	0t		0t	
Total CO_2-eq	40,164 t		13,780 t	
Proportion of CO_2	99.1%		53.8%	
CO_2-eq/GWh	79,848 t		1,115 t	
CO_2 as previous proportion	99.1% =	79,130 t	53.8% =	618.7 t
CO_2 gr/kWh	79		0.62	
National average	27%		73%	
Icelandic kWh - Weighted Average	**21.45 gr CO_2**			

It is therefore assumed that the average kWh of electricity production from renewable energy in Iceland generates 21.45 gr CO_2, (or 0.02145 kg) and this number will be used as a proxy for the following calculations to find direct CO_2 emissions from accommodation sites all over the country. For comparison, the average CO_2 emission factor applied for electricity in European hotels is 90 gr/kWh (ECCE 2013). Furthermore, Bayer et al (2013) estimated that CO_2 emissions from geothermal power plants alone range from 4-740 gr/kWh. The weighted average for the Icelandic kWh is therefore considered within boundaries, despite the geothermal focus of the Bayer et al analysis. The calculations above also indicate that CO_2 emissions from hydropower electricity production is usually far less than from geothermal production.

In terms of the energy calculated later in the accommodation section (5.2), it involves total energy consumption and is not specifically divided between the kitchen or the hotel sector of the operation. It should also be noted for Grand Hotel Reykjavik that their number includes the laundry operation. Their laundry-room cleans linen for four other hotels in the capital area, and is no doubt responsible for a large part of their electricity usage. By way of comparison, in the annual Swan-report of Reykjavik City Hostel for 2012, it says that the percentage of energy consumption due to its laundry, dryers and washing machines was nearly 22%, therefore pointing out the obvious fact that the numbers for Grand Hotel Reykjavik could be a little distorted. However, it is assumed that it levels out since places like the Hótel Rauðaskrida send all of their linen to an individual contractor (Kolbrún Úlfsdóttir - owner, personal communication, February 2nd 2014). Thus, the laundry operations of hotels varies quite a lot and can have an effect on their emission numbers per visitor night.

Five camping grounds in Iceland were contacted and information about their operations requested in order to calculate the energy used per visitor night. The sample was chosen by a snowball method where Geir Gígja, the manager of Tjalda.is, a website where all the camping grounds in Iceland are listed, was contacted (personal communication, January 14th 2014). He could not provide this information, but suggested a supervisor of a camping ground which was likely to have some sort of information. That supervisor then suggested another and so on. Despite positive feedback from several camping grounds, five said they would send information, but only two provided the actual data. Unfortunately, more information from accommodation providers in Iceland was not obtainable within the timeframe of this research, as this could have assisted in reducing the variance in results.

Gas

The quantity of gas consumption was provided by the hotels. Only three use gas to some extent, either in the kitchen for cooking food or for decorative fireplaces in their lobbies. Restaurant activities were not included in the calculations, but it was impossible to divide the gas usage between these two sections. Due to the surprising popularity of camping among tourists, it was decided to incorporate all the gas into the calculations since so many travellers use the fuel for heating purposes, but undeniably also for cooking. The reason behind this decision was also partly due to the belief that the overall estimate is an underestimate.

The quantity of gas, usually indicated in kg on a yearly basis, was divided by the annual number of visitor nights to get quantity per person. That weight was then multiplied by three to get the total CO_2 emissions, as instructed for Propane-gas (C_3H_8) by Eggert Eggertsson, sales manager of Isaga, gas provider in Iceland (personal communication, April 1st 2014). One hotel provided the gas used in kWh for which the emission factor used was from British Columbia (2013) Emission Guidance, or 59.54 kg CO_2 per GJ (kWh=0.036GJ; Convertit.com 2002).

Next, the emissions factors relevant for attractions and activities will be explained.

4.5.3 Activities/Attractions

Each activity/attraction has been calculated per visit per tourist, as can be seen in Table 4.14 below. Explanations follow on concerning how the results were retrieved for each activity.

Table 4.14 CO_2 emissions (kg) per activity per guest/visit

Activities	Short description	CO_2 kg/visit or kg/activity per person
Geothermal swimming pools / nature baths	Swimming pools of The Reykjavik Sports and Youth Council (ITR).	0.05 kg CO_2/visitor
Museums / Exhibitions	National museum - 3.7 kWh per visitor	0.08 kg CO_2/visitor
Guided sight-seeing tours	Approx 260 km tour. 55 pax/67 l biodiesel	3.12 kg CO_2/trip
Whale watching	1.15 l diesel per pax:	4.05 kg CO_2/ passenger
Spas / Wellness	Excluded	-
Horse riding	Excluded	-
Boat trip (other than whale watching)	2hr journey with 65 pax/120l diesel	5.58 kg CO_2/trip
Glacier / Snowmobile trip	1hour trip: 7l fuel per pax	17.96 kg CO_2/trip
Guided hiking / mountain trips	340km tour. 7pax in a Toyota Hiace (221 gr CO_2/km)	10.54 kg CO_2/trip
Other cultural events (Theatre, concerts, etc.)	Typical rock concert at Laugardalshöll, Reykjavik – 1.125 kWh per guest	0.02 kg CO_2/guest

For the general activities like day-tours, whale watching and hiking tours, the companies usually offer a shuttle service, i.e. they pick-up their customers at a pre-arranged location and drive them to the activity site. This distance is variable depending on the activity chosen and place of pick up. The type of vehicle also varies extensively and often changes from one year to the next. During the conduct of this research, the pick-up vehicles ranged from being a Toyota Hiace with an emission factor of 221 CO_2/km to a large Ford Econline with approximately 500 gr CO_2/km.

Instead of calculating each vehicle for each activity, a generalized pick-up vehicle was decided for all smaller pick-up and drop-off activity choices in Iceland.

A Mercedes Sprinter is the preferred pick-up vehicle by Reykjavik Excursions (RE), one of the largest tour operators in Reykjavik, mainly providing day-tours from the capital. Part of their services is complimentary pick-up from hotels, either for paid day-tours or passengers of the Flybus. Departure is from BSI bus terminal and the average pick-up radius from BSI is 5 km. Their Sprinters have 16 seats on average, run on biodiesel and have a fuel economy of 14.6 l/100km (Jóhanna Hreiðarsdóttir, HR-manager - personal communication, January 27th 2014).

This means that the Sprinter burns 0.146 l/km. With equation four (4) and the emission factor for diesel with *average biofuel blend* (DEFRA 2012), the following results emerge:

Average fuel consumption:	0.146 l/km	(14.6/100)
Emission factor biodiesel:	2.564 kg CO_2/l fuel	
Total CO_2 per km:	0.374 kg.	(0,146*2.564)
Average load factor:	78% = 12 pax	(See Guided hiking/mountain trips)
CO_2 pkm:	0.031 kg.	((0.374/(1*12))

The Sprinter was chosen as the default vehicle for all shuttle services, unless otherwise noted. The Sprinter was considered to be a good vehicle to represent the average shuttle-car in Iceland since its CO_2 emission per km (374 gr) is only 2.5% higher than the average of three pick-up vehicles, or 365 gr CO_2/km: the Toyota Hiace (221 gr CO_2/km), the Sprinter (374 gr CO_2/km) and the Ford Econline (approximately 500 gr CO_2/km).

Next, CO_2 emissions for each activity or attraction site are calculated per visit/trip.

Geothermal swimming pools / nature baths

The Reykjavik Sports and Youth Council (ITR) is responsible for operating all the swimming pools in Reykjavik city. The manager, Steinþór Einarsson and Andreas Andreassen, the financial manager, provided information on both electricity usage and total visitors from six swimming pools in 2011. The electricity usage in kWh per person was in the range from 1.5-2.8 kWh, with the average being 2.2. When that was multiplied by the CO_2 emission factor for electricity in Iceland, 21.45 gr/kWh the result was 47.4 gr CO_2 per visit.

Museums / Exhibitions

One museum gave a satisfactory reply regarding its energy use with the assistance from Reykjavik Energy. The Icelandic National Museum is located on Suðurgata 41 in Reykjavik. The 4,548 m^2 museum, consisting of both an exhibition house and offices, is estimated to have used 381,959 kWh in 2011 (Yngvinn Gunnlaugsson, service agent of Reykjavik Energy, personal communication, April 7th 2014).

According to the National Museum´s annual report from 2012, the total visitor numbers in 2011 was 101.999. By dividing the electricity usage with total visitors, the emissions per guest can be estimated, whether they originate from tourists or not.

Electricity consumption per guest/visit:	3.7 kWh	(381,325/101,999)
Emission/visit (gr):	79.4 gr CO_2	(21.45*3.7)
Emission/visit (kg):	0.08	

Guided sight-seeing tours

According to the ITB-survey the most popular sites visited are the main attraction magnets incorporated in the Golden Circle, i.e. Thingvellir, Gullfoss and Geysir. Consequently, this route is also a popular commodity among tour operators.

Reykjavik Excursions offer an eight hour Golden Circle tour covering 260km. The

coach used for this analysis was RE´s VDL coach with an estimated fuel economy of 25.8 l/100 km. It is recognised that all three tourist types travel the Golden Circle themselves, but there are many other tours that tourists can chose from, for example a tour along the south coast of Iceland to Vík in Mýrdal, which is about 380 km round trip, and a tour to the Snæfellsnes-Peninsula, which is approximately 460 km round trip. There is also a tour around the Reykjanes peninsula with an optional visit to the Blue Lagoon.
Therefore, in the hypothetical scenario for a guided sightseeing tour, the Reykjanes day tour was chosen since it includes both the Blue Lagoon and covers approximately the same distance as the Golden Circle tour.

Total fuel consumption:	66.95 l of biodiesel	(1401-0.33)
Emission factor biodiesel:	2.564 kg CO_2/l fuel	(IPCC 2006)
Total CO_2:	171.66 kg.	(66.95*2.564)
CO_2 per passenger:	3.12 kg.	(171.66/55)

Whale watching

According to Stefán Guðmundsson, owner of the whale watching company *Gentle Giants* in Husavik, northern Iceland, the typical tour burns 1-1.5 l of fuel per passenger – where the midpoint is 1.25 l (personal communication, January 20th 2014).
Here, HFO is used as the default fuel choice for all ocean going ships in the tourism industry in Iceland, and the relevant emission factor is extracted from the IPCC (1996) for its specific energy content.

Fuel consumption per pax:	1.25 l of HFO	
Energy intensity of HFO	41.727 MJ/l	(Oilsandreview.com)
Total energy:	52.160 MJ	(1.25*41.727)
Emission factor:	77.6 gr/MJ	(IPCC 1996)
CO_2 per passenger:	4.05 kg	(52.16*0.0776)

Spas/Wellness and Horse riding

The energy consumption involved in the activity choices *Spas/wellness* and *horse riding* was excluded from this research. The reason was mainly due to lack of information since it was unobtainable from two local spa centers who were contacted. The possibility of double counting also arose since many sites already contacted for the accommodation section offered their guest complementary access to spas, wellness centers or gyms of some kind, which was then already included in the accommodation sites´ electricity consumption.
The horse riding tour was excluded for the same reasons – one of the hotels/guesthouses (Eldhestar) in the accommodation section emphasised horse riding tours. Its total operations are therefore already accounted for in the calculations for them as a hotel/guesthouse, at least for that individual accommodation choice.

Boat trip (other than whale watching)

Pétur Ágústsson, general manager of Seatours, gave information on the fuel consumption of their vessels during tours. *Seatours* operate Baldur, the scheduled car-ferry from their base in Stykkisholmur to Brjanslaekur on the Vestfjords, with a short stop in Flatey. They also offer various cruises from Stykkisholmur, the most typical one being a two hour tour in Breidafjordur. The vessel can take up to 144 passengers and usually burns 120 l of marine diesel per trip The average passenger load factor for Baldur is 45% and Pétur Ágústsson agreed that the same ratio could also apply for the shorter tours, or 65pax (personal communication, February 17th 2014).

Total fuel consumption:	120 l of HFO	
Emission factor HFO:	3.118 kg CO_2/l fuel	(IPCC 1996).
Total CO_2:	374.6 kg.	(3.118*120)
CO_2 per passenger:	5.75 kg.	(374.6/65)

Glacier / Snowmobile trip

According to Gylfi Sævarsson, the owner of snowmobile tour-company Vélsleðaleigan [e. Snowmobile Rental], the most typical journey chosen by 80% of his customers only takes one hour (personal communication, January 21st 2014). His snowmobiles burn 7.0 l of petrol on average per hour and usually there is one person per snowmobile. There is also a 60 km transit involved since snow is usually to be found in higher altitudes or on glaciers further away from the capital area, especially during summer. For that transit the default pick-up vehicle (Sprinter) is used, since vehicle types can vary considerably between tour-companies.

Total fuel consumption:	7.0 l of petrol	
Emission factor - Petrol:	2.3018 kg CO_2/l fuel	(IPCC 2006)
Total CO_2:	16.1 kg.	(2.3018*7)
CO_2 per passenger:	16.1 kg.	(16.1/1)

In this case, one passenger in the Sprinter (0.031 kg CO_2/pkm) is responsible for 1.86 kg (0.031*60) of CO_2. Therefore, making the total of 17.96 kg (16.1+1.86) per person for a snowmobile trip.

Guided hiking / mountain trips

A representative of *The Icelandic Mountain Guides*, Andrea Burgherr, said that their most popular trip is a day-tour consisting of a 4-5 hour hike (personal communication, April 2nd 2014). The trip consists of a 340 km travel in a car, usually a Toyota Hiace which has the emission factor of 221 gr CO_2/km but, as before, the default vehicle is used. Andrea also said that usually there are 7 passengers in a 9 seat car, which equates to a 78% load factor.

The information on load factors is convenient since many tour-companies did not specify it. It is important to have some sort of criteria for guidance since it is unlikely that activity tours are continously run at full capacity. The load factor of 78% will therefore be used as a default load factor where it is unknown.

In this case, one passenger in the Sprinter (0.031 kg CO_2/pkm) is responsible for 10.54 kg of CO_2 during his 340 km drive to the guided hiking / mountain trip.

Other cultural events (Theatre, concerts, etc.)

Óli Öder, manager of Laugardalshöll, a large sports hall which is also used extensively as a venue for concerts and other cultural events, provided information about a typical rock concert. Óli estimated that it uses 8-10,000 kWh and can be attended by 5,500-10,000 people. Óli agreed that it would not be unfair to say 9,000 kWh and 8,000 people would attend a typical show (personal communication, April 7th 2014).

This means the average guest at a rock concert consumes 1.13 kWh (9,000/8,000) and if that is multiplied by the CO_2 emission from the average Icelandic kWh (0.02145 kg), this tourist is responsible for emitting 0.02 kg of CO_2 into the atmosphere.

4.6 Summary

In this fourth chapter the methodology applied in this analysis was described. First of all, the tourists who answered the ITB-survey conducted in the summer of 2011 were catagorised into three types; low, medium and high – according to their income and age, but profession was also a determining factor. It is assumed that income is interlinked with increased consumption. The tourist will indulge himself more and have higher demands in terms of transport, accommodation and activities/attraction sites as his income increases. The choices of each tourist in terms of transportation were described, where the low consumption tourist is the only one to travel with an international ferry, while the other two use airplanes, one from North-America and another from Europe. Their trip lengths and mode of transportation are different, but trip lengths were estimated from rental car periods and the total average trip lengths among the particular income group. Low consumption tourist types stayed for 16 nights on land and mostly travelled using scheduled buses, while medium and high use tourists hired cars (Fiesta and Explorer) while staying 11 and 7 nights respectively. During their travel on Iceland´s ring road number 1 they stay at different regions for varying durations, but the capital area is undeniably the most popular among all of them. With the assistance of equation one, the trip lengths were scaled and reflected onto relevant regions and accommodation types. Choices of accommodation type is also different between the tourist types, but they were hotels/guesthouses, hostels/lodges and camping/caravan sites. Low consumption types enjoyed the camping sites most often, while the other two enjoyed indoor accommodation more often. Choices of activities and attractions are similar among all tourist types. Visits to swimming pools/nature baths, museums, whale watching and snowmobile tours stand out, and after assistance from ITB, the individual tourist choices could be identified for the scenarios used in this analysis.

Finally, the emission factors relevant to this study were explained. In the transportation section, both fuel-based and distance-based methods were applied in order to get a CO_2 weight. A few equations were introduced to calculate emissions, e.g. from airplanes (eq. 2), ships and boats (eq.4), and various road transportation devices (eq.5). Equation three can apply to all in order to calculate emissions per passenger kilometre. Issued load factors for the flights/cruise, are fully trusted and applied in this analysis since all paying passengers are made accountable for their individual emissions during that particular journey.

Energy production in Iceland was evaluated and the environmental cost in terms of CO_2 for the production of an average Icelandic kilowatthour of energy was estimated. In the end, CO_2 emissions from a few activity choices were estimated in terms of their energy use, either from electricity or fuel.

In the next chapter the results will be revealed along with some general discussions.

5 Results and discussions

In the following chapter the results will be revealed along with some general discussions. First the emissions from the selection of transportation modes are explained, followed by the accommodation and then attractions and activity choices. An overall picture of the emission per tourist is given in section 5.4.

5.1 CO_2 from transportation

Transportation modes were several, e.g. Smyril Line´s international ferry Norröna, a Boeing 757-200 and various road vehicles. The following are the estimated CO_2 emissions for each transportation mode and how they were calculated. This chapter relies on information already provided in chapter 4.5 on emission factors. Explanations follow on concerning how the results were retrieved for transportation, accommodation and attractions/activities.

5.1.1 International transportation

In Table 5.1 the emissions from international transportation are depicted. Those are mainly the ferry Norröna and the Boeing 757-200 operated by Delta Airlines.

Table 5.1 Total CO_2 emissions (kg) for international transportation

International travel mode	Low	Medium	High
Ferry (Norröna)	694.5	-	-
Airplane (Boeing 757-200)	-	427.8	723.0

Smyril Line - Ferry

During Norrönas´ cruise to Iceland its fuel consumption was 124 t, thus making its total one-way CO_2 emission 386.1 t (3.114*124). Per person, the emissions equate to 347.2 kg (386,136/1,112). For a return trip the total emissions are estimated to be double (2*347.2), or 694.5 kg CO_2.
This number is surprisingly high. Because ships travel slower than airplanes, one automatically relates that to less fuel consumption and more efficiency but these results show otherwise. It is also strange that IMO (2014) maintains that ships are “environmentally friendly and fuel-efficient mode of transport” (IMO 2014a, p.2). It would be interesting to know what they are comparing that to. One would also think that the ships passenger capacity would help to keep the CO_2 weight per person down but the quantity is so enormous that it does not help.

Airplane - Medium Consumption (FRA-KEF)

The result from the FRA-KEF flight with equation two issued by ICAO is 213.9 kg of CO_2 per passenger ((10,443*0.9812)/(181*0.8355)*3.157) during one way flight, and to incorporate the return flight, the one-way emissions are simply doubled and are thus 427.8 kg. With equation three the CO_2 per pkm in this case is 89 gr ((213.9*181)/(181*2,402)), which is relatively close to what the Forest Carbon Group (2014) estimates in their explanation to their own CO_2 calculator for flights. For an economy class seat in a long-haul flight with 77.8% load factor, the typical CO_2 emissions pkm were 81.9 gr and 93.6 gr for short-haul flights. Their calculator is based on an analysis of 16 different airlines and their various types of passenger airplanes, either Boeing or Airbus in 2009.

Airplane - High consumption (JFK-KEF)

With equation two issued by ICAO the result from the JFK-KEF flight gives 361.5 kg of CO_2 per passenger ((17,223*0.9812)/(181*0.812)*3.157) during one way flight, or 723 kg including the return flight. With equation three the CO_2 per pkm in this case is 87 gr ((361.5*181)/(181*4,168)) which is also within the range estimated by the Forest Carbon Group (2014). To ensure correct calculations, the *Carbon Emission Calculator* on ICAO website was visited and the two airports (JFK-KEF) paired together. The calculator automatically assumes a 203 seat aircraft but the total emission per pax was 334.9 kg of CO_2 for one-way (ICAO 2011b). The difference it not substantial and can probably be traced to some extent to a larger denominator (203) on the ICAO website.

5.1.2 Domestic transportation

In terms of emissions due to domestic transportation, the overall direct CO_2 emissions from all three tourist types can be seen in table 5.2.
The calculations and results are further explained in the following section. Indirect emissions within scope 3 (associated with extraction, refining, distribution and storage of fuel) are outside the scope of this research.

Table 5.2 Total CO_2 emissions (kg) for domestic transportation

Domestic travel mode	Low	Medium	High
Round-trip	82.7	117.4	386.3
Taxis and buses	-	1.28	6.71
Total CO_2 (kg)	82.7	118.7	393.0

When the emissions due to their individual round trip on ring road number 1 are added to the emissions from taxis and buses, the following results emerge. The low consumption tourist is estimated to be responsible for directly emitting 82.7 kg of CO_2 and the medium 118.7 kg of CO_2. The high consumption tourist emits 393 kg of CO_2, equivalent to more than three times the emissions of the medium consumption type.

Low consumption tourist

Backpacker bus/coach

With the estimated average fuel consumption of 0.33 l per/km and the total distance travelled by low consumption tourist, 1,401 km, the total fuel consumption can be calculated via a fuel-based approach.

Total fuel consumption:	462.3 l of diesel	(1,401*0.33)
Gravity factor of diesel:	1.159	(CBI 2013)
The weight is therefore:	398.9 kg	(462.3/1.159)
Emission factor of diesel:	3.14 kg CO_2 per kg fuel	(IPCC 1996)
Total CO_2:	1,241 kg.	(398.9*3.14)
CO_2 per passenger:	82.7 kg.	(1,241/15)

Low consumption tourist emits 82.7 kg of CO_2 during his trip on board buses/coaches in Iceland. The bus/coach is not given the 19% uplift factor since the emission factor was calculated from actual fuel consumption of similar coaches used in this analysis.

Transportation from Keflavik airport

The coach used for transportation from Keflavik Airport to Reykjavik was the VDL Futura from Reykjavik Excursions (RE), which operates the Flybus. Usually, the Flybus is full in the summer time (Jóhanna Hreiðarsdóttir, HR-manager, personal communications, January 27th 2014). The distance from Keflavik to Reykjavik City Center is approximately 51 km (here.com). The bus usually has to wait in a queue at the airport where stop and go is repetitive for a relatively short distance. Often the engine runs the whole time. The bus also stops at two places on its way to/from the airport through the capital area - therefore an extra 2 km is added for on and off highway detours and other fuel consumption, i.e. stop and go. The one-way distance is therefore set at 53 km.

With the fuel-based approach for one way the CO_2 emission will equate to:

Average fuel consumption:	0.258 l/km	(25.8/100)
Total fuel consumption:	13.67 l of biodiesel	(0.258*53)
Emission factor biodiesel:	2.564 kg CO_2/l fuel	(IPCC 2006)
Total CO_2:	35.05 kg.	(13.67*2.564)
CO_2 per passenger:	0.64 kg.	(35.05/55)

Thus, for medium consumption tourist travelling both ways with the Flybus, it will equate to 1.28 kg CO_2 (0.64*2).

Medium consumption tourist

Rental car (Ford Fiesta)

The route travelled by the medium consumption tourist is 2,007 km long. According to Waddington (2009), the Ford Fiesta has a CO_2 emission factor of 98 gr/km, but after applying the uplift factor of 19%, it increases to 117 gr/km.

With the distance-based approach, the CO_2 emissions will equate to:

Emission factor per km:	117 gr/km	
Total CO_2:	234.8 kg	(0.117*2,007)
CO_2 per passenger:	117.4 kg	(234.8/2)

Total emission from medium consumption tourist due to domestic transportation choices is therefore 118.7 kg CO_2 (117.4+1.28).

High consumption tourist

Transport from KEF to Reykjavik with taxi.

The Mercedes Benz E, 2005 model, which transfers the high consumption tourist and its spouse from Keflavik Airport to Reykjavik, is given an uplift of 19%, increasing it to 213 gr/km (179*1.19).

With the distance-based approach, the CO_2 emissions will look like this for one-way travel:

Emission factor per km:	213 gr/km	
Total CO_2:	10.86 kg	(0.213*51)
CO_2 per passenger:	5.43 kg	(10.86/2)

Rental Car (Ford Explorer)

The route travelled by the high consumption tourist is 1,768 km long. According to the US Department of Energy (2014), the CO_2 emission factor of a Ford Explorer 2010 model was 367 gr/km. The emission factor is given an uplift of 19%, increasing it to 437 gr/km.

With the distance-based approach, CO_2 emissions equate to:

Emission factor per km:	437 gr/km	
Total CO_2:	772.6 kg	(0.437*1,768)
CO_2 per passenger:	386.3 kg	(772.6/2)

Due to high consumption choices in domestic transportation, i.e. rental car use (386.3 kg), taxi transportation from airport (5.43 kg) and Flybus back to aiport (1.28 kg) this tourists total CO_2 emissions will therefore become 393 kg

Regarding the emissions from both rental cars, it should be especially noted that for the medium and high consumption tourists, the total emissions are divided with two persons (tourist and spouse) to get per person emission, albeit this sounds unfair somehow. The car´s engine always emits CO_2, and the weight factor certainly playes a large role since the number of passengers can give an indication of how much fuel it will consume. However, the load factor of one or two persons should not make much difference to the total fuel consumption. Nevertheless, since the purpose of this analysis was to estimate per person CO_2 emissions, the weight must be divided by the passenger number, despite it giving a slightly distorted result.

It is also worth mentioning that in the calculations for RE vehicles, it is anticipated that they use biodiesel (they usually prefer to) which, compared to most tour operators in Iceland, isn´t the typical choice of fuel because it is slightly more expensive. RE chooses it to reflect positive environmental credentials, since one litre of biodiesel emits less CO_2 than regular diesel (2.56 kg CO_2 opposed to 3.14 kg).

5.2 CO_2 from Accommodation

In Table 5.3 the direct CO_2 emissions from different accommodation choices in Iceland in 2012 can be seen. Their sizes vary considerably, both in room numbers and square meters (m^2) and for comparative reasons only, these are presented for all accommodation choices in this analysis. All the numbers apply to 2012 except for the camping grounds, which was from 2011. This was due to an unfortunate typing error which was discovered late in the process. It is not expected to have dramatic effects on the results of this research since no major changes occurred between those years in regards to the management of the accommodation choices, e.g. either implementing or departing from an environmental management system.

It shall be noted that the accommodation type *hostels/lodges in wilderness and similar* has been shortened here to *hostel and similar* and that calculations of CO_2 per visitor night anticipate that the average Icelandic kWh emits 0.02145 kg CO_2, which was estimated in section 4.5.2.

All accommodation providers had some kind of environmental management system (e.g. Swan-label or EarthCheck) that helped facilitate the data gathering process. However, due to low responses from accommodation providers, Table 5.3 is built on very limited data, which is an acknowledged flaw.

Furthermore, step-by-step calculations on all gas and energy consumption per person are intentionally left out in this section. This is certainly unfortunate due to its lack of transparency and its demand of trust from the reader. This approach is due to the request from most accommodation providers of not to mention their number of visitor nights. It is impossible to show two numbers together since the third can easily be calculated from there.

Table 5.3 Direct CO_2 emissions (kg) of different accommodation choices in 2012

Accommodation	Area	Rooms / Size of facility (m^2)	Category	Kwh / visitor night	Gas, CO_2 kg/ visitor night	Total CO_2 kg/ visitor night
Grand Hotel Reykjavik	Capital	311 / 18,337	Hotel / Guesthouse	63.6	0.07	1.44
Hotel Eldhestar	South	26 / 1,177	Hotel / Guesthouse	20.52	0.19	0.63
Hotel / Guesthouse Rauðaskriða	North	34 / 1,100	Hotel / Guesthouse	3.41	0.14	0.22
Icelandair Hotel Natura	Capital	220 / 12,567	Hotel / Guesthouse	18	0.08	0.47
			Hotel / Guesthouse		**Average:**	**0.69**
Hostel Reyðarfjörður	East	13 / 323	Hostel and similar	21.4	0.004	0.46
Reykjavik City Hostel - Laugardalur	Capital	41 / 2,036	Hostel and similar	3.41	0.004	0.08
Reykjavik Downtown Hostel Vesturgata	Capital	19 / 757	Hostel and similar	2.96	-	0.06
			Hostel and similar		**Average:**	**0.20**
Camping – Laugum	North	-	Camping	6.8	-	0.15
Camping - Systragil	North	-	Camping	0.9	-	0.02
			Camping		**Average:**	**0.08**

Source: Hotel websites, personal communications with managers, Registers Iceland)

Nevertheless, the table provides an estimate of direct CO_2 emissions from different accommodation choices available throughout the country. From an analytical viewpoint, it is a shame that electrodes circulating the Iceland´s power grid are not marked with their origin of production, but technological availability most probably plays an extensive role there. If all the kWh-numbers (9) are added together, it equates to 141, from which it can be estimated that the average visitor night in Iceland consumes 15.6 kWh, while the global average is 130 MJ (UNWTO-UNEP-WMO 2008) or 36.1 kWh (convertit.com). By way of comparison, the average electricity consumption per visitor night in popular Torremolinos, Spain in 2008 was 35.9 kWh (Bourse 2011). The reason behind this low kWh-number in Iceland could possibly be traced to a reduced need for indoor lighting due to daylight situations almost the entire summer. Furthermore, on Icelands´ hot zones, there is plenty of hot water, eliminating the need to heat up cold water with electricity.

The accommodation choices are sectioned into three categories and an effort has been made to find the average emissions from each accommodation type. For further explanation, there are four *hotels/guesthouses* that make the entire section. The gap between the two largest hotels is considerable, Grand Hotel Reykjavik, situated in the capital area with 311 rooms and spanning 18,337 m^2 of floor area, burns 63.6 kWh and 0.07 kg CO_2 of propane-gas per visitor night.

With the assistance of the CO_2 emission factor for the average Icelandic kWh (0.02145 kg), the total CO_2 emission per visitor night will equate to 1.44 kg (63.6*0.02145+0.07), while one visitor at Icelandair Hotel Natura emits 0.47 kg CO_2 per night. Due to this gap, it was decided to find the average from all of the hotels and guesthouses, i.e. from four accommodation providers, and the result was 0.69 CO_2 kg/visitor night. However, regarding the hostel and similar category, there were only three hostels that provided information to support this study: the Reykjavik City Hostel in Laugardalur, Reykjavik Downtown Hostel in Vesturgata and Hostel in Reyðarfjörður, where the categories overall average is 0.20 CO_2 kg/visitor night. Both the hostels in Reykjavik are operated according to a commendable sustainability paradigm and are very environmentally conscious. In 2012 they received an award for being the lowest CO_2 emitting hostels within the worldwide Hostelling International Network (Emilia Prodea, personal communication, February 10th 2014). Their average CO_2 kg/visitor night was 0.01. However, when the hostel at Reyðarfjörður, which is only open during high season, was included, the average was pushed up to 0.20 CO_2 kg/visitor night. This could be an indication of how important environmental management systems are. It is therefore likely that if those accommodation providers who think less about the environment (or not at all) would contribute data, the results would be somewhat different.

Finally, only two *camping and caravan sites* make up their section, with the average of 0.08 CO_2 kg/visitor night. The lowest emissions of all accommodation providers was from the camping site at Systragil where the kWh per visitor night was only 0.9, thus emitting only 0.02 kg of CO_2 per visitor night.

The standard deviation from the average is quite extensive in all accommodation categories: +/- 0.53 kg CO_2 for hotels and guesthouses, +/- 0.19 for hostels/lodges and similar accommodation, and +/- 0.06 kg CO_2 for camping and caravan sites.

In comparison to Sisman and Associates (2007) and Becken and Patterson (2006), the CO_2 emissions per visitor night is usually on a much larger scale. The reason for this most probably derives from differences in electricity generation, since the majority of the world produces its energy through the burning of fossil fuels.

In Table 5.4 the CO_2 emissions for accommodation has been categorised according to tourist and accommodation types. The numbers inside the brackets are number of nights stayed in relevant accommodation. The low consumption tourist stayed two nights in hotels/guesthouses, where his total emissions were 1.38 kg CO_2. He stayed five nights in hostels/lodges and similar accommodation, where his total emissions were 1.00 kg CO_2. He then stayed nine nights in camping and caravan sites, where his emissions were 0.74 kg CO_2. Therefore, during his total stay of 16 nights on land, he was responsible for emitting 3.12 kg CO_2. The medium consumption tourist was responsible for emitting less, only 2.06 kg, while the high consumption tourist emitted the least, 1.45 kg CO_2, during their stay in Iceland. This may look strange but in the light of the total assumed duration of each tourist, the numbers resonate.

Table 5.4 Total CO_2 (kg) per tourist type for accommodation type

	CO_2 kg/ visitor night	Low Consumption	Medium Consumption	High Consumption
Hotel / Guesthouse	0.69	(*2) 1.38	(*2) 1.38	(*1) 0.69
Hostels and similar	0.20	(*5) 1,00	(*3) 0.60	(*3) 0.60
Camping	0.08	(*9) 0.74	(*1) 0.08	(*2) 0.16
Total nights		16	11	7
Total CO_2 kg per night		3.13	2.06	1.45

Due to limited data in this section, it is not believed to be an accurate estimate since the variation factor is so high in these calculations. It would have been good to have a large population of various accommodation providers to apprehend information so that this section could have been done more thoroughly. Additionally, in terms of CO_2 emissions for the average Icelandic kWh, it could easily be material for another Masters´s thesis.

5.3 CO_2 from attractions and activities

The overall emissions for attractions / activities can be viewed in Table 5.5 for each tourist type. High consumption choices bear the highest carbon footprint out of the three.

Table 5.5 Total CO_2 (kg) per tourist type for chosen activities / attraction sites

	Low Consumption	Medium Consumption	High Consumption
Geothermal swimming pools / nature baths	-	0.05	0.05
Museums / Exhibitions	0.08	0.08	0.08
Whale watching	4.05	4.05	4.05
Snowmobile trip			17.96
Total CO_2 kg	4.13	4.18	22.14

As previously stated with regards to the low consumption tourist, their activity choice of spa/wellness was excluded. However, due to other consumption choices made by these tourists, i.e. a visit to a museum and whale watching, their CF is 4.13 kg CO_2. The medium consumption tourist undertook the same activities as the low consumption type, but in addition he went swimming, thus making his CF slightly higher at 4.18 kg CO_2. The high consumptions tourist did all the same activities as the medium one, but he added a snowmobile ride to his experience of Iceland, making his CF a total of 22.14 kg CO_2.

As previously stated, it was difficult to pinpoint which 1-2 activies from the overall list of paid activities should be included in the CF calculations for each tourist type. All three tourist types analysed here seemed to choose the same activities/attraction sites. The unreliability must also be reinforced by the observation that these calculations relate to the specific choices of only one tourist in each income category.

5.4 Overall CO_2 emissions

In Table 5.6 the overall CO_2 emissions for each tourist type has been summarized. It should be noted for the low consumptiontourist that his total trip duration is now 20 days, since his four nights on board Norröna (while enjoying its hotel/accommodation functionalities) have been added to his 16 day on-land duration. The medium consumption tourist stayed 11 nights overall and high consumption tourist stayed 7 nights.

Table 5.6 Overall CO_2 emissions (kg) from all tourist types in all sectors

	Low	Medium	High
Transportation - International	694.5	427.8	723
Transportation - Domestic	82.7	118.7	393
Accommodation	3.13	2.06	1.45
Attraction / Activities	4.13	4.18	22.14
Total CO_2 emissions	784.46	552.74	1,139.59
CO_2 emission per day (kg)	**39.22**	**50.25**	**162.80**

The total emissions for international transportation weigh the highest out of all tourist types. The high consumption tourist sits at the top of this category, since his emissions are 69% higher than those of the medium, but high consumption also flies considerably more, or 1,760 km. However, low consumption tourist emits 63% more than medium despite the fact that both are coming from Europe.

In domestic transportation the emissions from the high consumption tourist are more than threefold the quantity of what the medium consumption tourist emits via his choices, despite both using rental cars. Here, the type of car certainly makes a difference but also the total distance travelled.

A low consumption tourist is responsible for the highest emissions out of the three in terms of accommodation, 3.13 kg CO_2, while a high consumption tourist has little more than half of that, 1.45 kg CO_2. The overall choices made by high consumption tourist in accommodation were surprising since it was believed that due to his financial capabilities and relatively quick trip, he would more often chose a more easier way of accommodation, e.g. hotels. High consumption tourists are also responsible for the most emissions in the activity/attraction sites category, with 22.14 kg CO_2 while low and medium consumption tourist are have a similar CF in that category, of 4.13 and 4.18 kg respectively.

Figure 5.1 portrays the total emissions per tourist per day in kilogrammes.

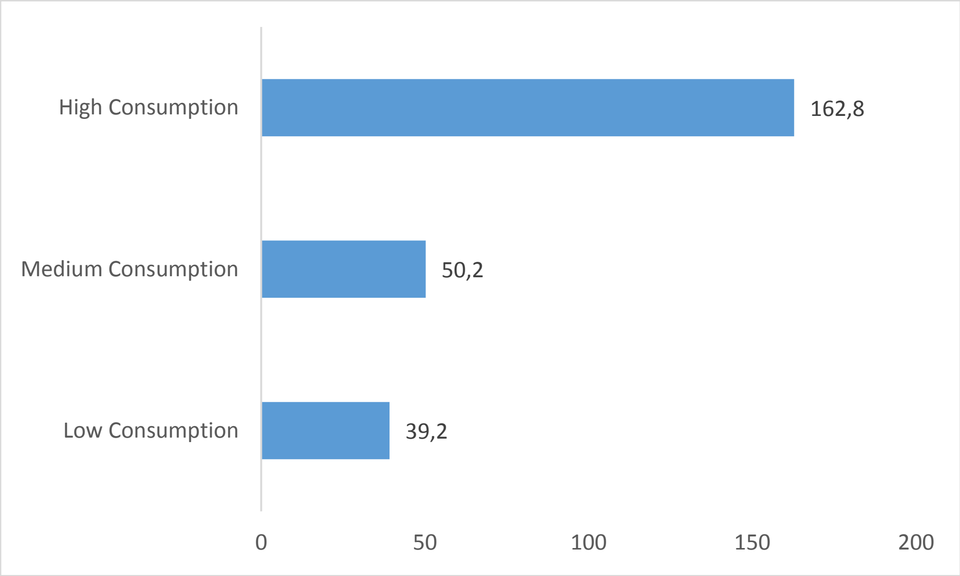


Figure 5.1 Total CO_2 emissions (kg) per tourist per day

The low consumption tourist has the lowest CF per day out of the three, with 39.3 kg CO_2 per day. The medium consumption tourist is responsible for emitting 50.2 kg of CO_2 and the high consumptioun tourist has the highest CF, with 162.8 kg CO_2.
These numbers are not particularly far from the results of De Bruijn et al (2012) on Dutch holidaymakers, who calculated the average CF for tourists of 62 kg CO_2 per day when abroad.

It can therefore be asserted that if all foreign tourists in Iceland behaved like the in this analysis, the direct CO_2 emissions from the 565,611 tourists in 2011 would sum up to either 15,498 t (low), 28,393 t (medium) or 92,138 t (high) respectively. In the case of the low consumption tourist, this would equate to 0.5 % of the country´s total CO_2 emissions, which were 3,333,000 t in 2011 (EAI 2013); medium consumption would equate to 0.9%; and high consumption could be responsible for 2.8% of the Iceland´s total CO_2 emissions.

5.5 Summary

In this chapter it has been estimated that an international ship transporting tourists to and from Iceland emits 694.5 kg CO_2 per passenger. A return passenger travelling via a Boeing 747-200 to Iceland from Frankfurt emits 427.8 kg of CO_2 and a return passenger from New York emits 723 kg. The three tourist types chose different transportation methods domestically. It was estimated that the high consumption tourist emits 393 kg of CO_2 during their stay; medium emits 118.7 kg of CO_2; and low emits 82.7 kg of CO_2. In the accommodation sector, high consumption tourists emit the lowest (1.5 kg); medium types are responsible for the second most emissions (2.1 kg); and low consumptioun tourists the most emissions in this section (3.1 kg CO_2).

In the next chapter some main conclusions of the research will be drawn out.

6 Conclusion

The main purpose of this research was to attempt to estimate the carbon footprint of the average foreign tourists in Iceland, measured in kilograms of CO_2 per person per day through their direct emissions in transportation, accommodation and activities / attractions.
Scope 3 emissions (secondary) were left out, which immediately gives reason to believe that the outcomes are certainly an underestimate, however, they are within the confines of this research and its objectives. Other objectives of this study were to identify the most significant contributing factors (hot spots) of CO_2 emitted by tourists and to explain what can be done in terms of mitigation methods to reduce the negative impact. In the following chapter a discussion on the CO_2 estimate and main contributing factors take place simultaneously, followed by a discussion on possible mitigation methods.

The main conclusion of the study, according to the hypothetical scenarios largely built on the responses from the extensive ITB survey, the average tourist in Iceland emits 50.2 kg of CO_2 per day, based on medium consumption behaviour – opposed to the average Dutch carbon footprint abroad, or 62 kg CO_2 per day.
The low consumption tourist emits 39.2 kg of CO_2 per day and high consumption tourist 162.8 kg of CO_2 per day. Since the medium consumption tourist´s scenario is built on the most typical answers in each category, it should give us the CO_2 emissions from the most typical, average tourist that visited Iceland in the summer of 2011. There is no specific reason to believe that the tourist types who visit Iceland have changed much since then (e.g. similar nationalities), so the results should also give an indication of the current status. In fact, domestic international tourism consumption per tourist has increased by approximately 2% since 2011, compared to 2013.

Tourism consumption behaviour as described here is not a large contributor to Iceland overall CO_2 emissions, ranging from 0.5 to 2.8% depending on which tourist is analysed. Nonetheless, it is amusing to reflect the numbers from Table 5.6, for example on the average Icelandic CF, which was 10.7 t for 2011. If an Icelander would behave like low, medium and high consumption tourist for a whole year, his CF per year would be, 14.3 t, 18.3 t and 59.5 t respectively, including the international transportation. If international transportation is however excluded, it plummets down to 1.6 t, 4.2 t and 21.8 t for low, medium and high consumption tourist, respectively.

As expected for an island destination the international transportation mode (i.e. ships and airplanes) is the largest contribution factor. It was very interesting to see that emissions from these two transportation modes are not particularly far from each other. The CO_2 emissions from Norröna were especially surprising and further emphasise that large passenger ships need a tremendous amount of energy to travel. A flight-passenger travelling from Frankfurt emits 266.7 kg less of CO_2 than cruise passenger from Denmark, while a flight-passenger from North-America emits only 28.5 kg more than the Norröna passenger. Somehow the mind tells us that the gap between those two transportation modes should be much more, i.e. the loud, high-speed airplane should have much greater emissions. The IMO (2014) also bears some responsibility for that assumption. Additionally, in this analysis the typical summer load factor for Smyril Line (75%), was used to assume the quantity of tourists who would disembark and visit Iceland despite the fact that many passengers probably continue with the ship back to Denmark. Therefore, the total passengers who actually enter the country are less than 1112, thus probably making the carbon footprint of ferry passengers much higher than is estimated on these pages.

The aviation industry is responsible for 77% of the total emissions relating to the medium consumption tourist. For the low consumption tourist, international transportation is 88% of their total CO_2 emissions. It is quite disappointing that within the international framework for aviation there has not yet been found a way (or will) to attribute aviation emissions to individual economies. There is a special emissions framework in operation within the European Union but nowhere outside it. Hopefully, ICAO will soon encourage all its member nations to seek new ways to reduce their aviation CF, especially in the light of an expected global increase in tourism arrivals and thus aviation traffic, or 3.3% until 2030. The same would apply for the IMO – to encourage technological developments and mitigation methods to its members.

Furthermore, the price per ticket of the individual international transportation gives an indication that the price of carbon is most probably not included – Norröna´s passenger pays 75,941 ISK while the flight-passenger from Frankfurt pays 90,163 ISK. Taking an environmental perspective, this is something that deserves a closer inspection.

Overall, the second largest contributing factor is domestic transportation, responsible for 21% of the emissions from the medium consumption tourist. The emissions from transportation vehicles is quite large where the 4x4 jeep produces the largest CF, while the coach/bus imposes the smallest CF per person.

There are 36 kg of CO_2 between low and medium domestic transportation choices, where medium consumption tourist travels only with his spouse in a private/rental car most of the time. However, the low consumption tourist enjoyes a much larger denominator due to more passengers in buses. There are 310 kg of CO_2 between low and high consumption tourists, which shows that individual tourist choices in terms of domestic transportation have a large effect on their total CF. In relation to denominators it is also worth to re-mention that dividing the overall emissions from a vehicle with two persons seems unfair because it is likely that the emission from the vehicle does not change much whether there are one or two regular sized persons in it. However, same applies to most transportation vehicles. Therefore, to keep consistency and be within the confines of the research, this method was unavoidable. It is also worth mentioning that high consumption tourist spent slightly less (53,118 ISK) than medium consumption (54,835 ISK) on domestic transportation and the second least (20,410 ISK) out of the three in fuel related expenses (low; 18,897 ISK and high; 27,576 ISK). Perhaps the Ford Explorer is an overshoot for this tourist type? Nonetheless, this tourist also has the shortest trip, thus spending more per day.

It is quite surprising to see that the low consumption tourist has the highest emissions in terms of accommodation. Despite receiving the lowest income, this tourist has a relatively expensive taste in terms of accommodation, but then again, he spends the most nights in Iceland out of the three. It also sounds like an oxymoron to see that the emissions from high income tourists due to accommodation choices are the lowest out of the three. It shows, in this case, that one should beaware of making assumptions regarding high consumption tourists – many of them like to camp, thus emitting less CO_2. Therefore, despite more luxurious domestic transportation choices, their behaviour is not as harmful as might be anticipated. However, the calculated emissions from the accommodation sector have extensive deviations which could have been improved with more data from all accommodation types. Furthermore, the weighted average estimated for the Icelandic kWh is open for criticism. Landsvirkjun mainly produces electricity for whole-sale purposes for the heavy industry in Iceland. However, information about various emissions from their electricity production was easily accessible and the estimate used in this analysis was derived from their reports. It shall therefore be emphasised that the weighted average for the Icelandic kWh used in this analysis was believed to be the best guesstimate readily available

during this research period.
Regarding deviation, there is also a large deviation for attractions and activity choices. Here, a gap is left for others to hopefully fill in the future.

Following the results built on the constructed scenario for medium consumption tourist the largest contribution factor of CO_2 emissions is its international transportation, or 77% followed by domestic transportation, or 21%. Accommodation and activities/attraction sites are therefore only responsible for 2% of the total CO_2 emission during its tourism experience of Iceland. If these numbers are projected on global CO_2 emissions from tourism, issued by UNWTO (2011), or 5% (where 4% is estimated to come from transportation and 1% from the accommodation sector) the transportation would equate to 4.9% (98%*0.05) and accommodation and attractions/activities for 0.1%. This shows what transportation is a large contributor of overall CO_2 emissions from tourists in Iceland, actually exceeding the global average by approximately 0.9%. Accommodation and attractions/activities are propably so low in this case due to low emissions from energy production in Iceland and fairly low emission activity choices made by the tourists in this analysis.

The tourism industry can take many steps towards becoming a green industry and several suggestions have already been made in terms of mitigation methods to reduce the negative environmental impacts of tourism. Increased efficiency is a fundamental starting point when it comes to suggest a mitigation method to reduce negative impacts from tourism and tourism related sectors. Basic management of emissions can involve various methods, such as improved energy efficiency and technological solutions, and evaluation of processes, consumption and supply chains to name only a few. All stakeholders within the tourism sector should be strongly encouraged to set up an environmental management system (EMS) to monitor and review their environmental performance on a regular basis, in correlation with the Davos declaration from 2007. This should be done because with constant reviewing and monitoring, hopefully people become competitive and strive to improve their performance. After a certain adjustment/implementation period has passed, all companies should be obliged to return a green-accounting report to the local authorities or have enforced a globally recognised EMS (e.g. ISO14001, Nordic Ecolabel; Swan etc.) where surveillance by third party and regular reporting is mandatory. Preferably, the systems should be internationally recognised to make all comparison easier for future travellers.

Regarding tourists themselves, it is important to distribute information and point out the possible negative environmental effects that tourism behaviour can cause, not in order to reduce their participation but simply to enable an informed decision to be made. Car rentals usually make sure they have new cars available that should use less fuel and emit less CO_2 but their representatives could also make an effort to encourage the use of smaller and more efficient vehicles. They might also wish to establish a minimum passenger number (load factor) in order to rent the larger vehicles. In general, empty seats are a matter of inefficiency that should be reduced and tourists can participate in that. For example, by finding another couple to join the tour, increasing the load factor and thus, perhaps, tour companies can offer a green discount. This idea could also be redirected to the government, which could apply carbon tax, if the passenger number doesn´t exceed a certain number. This can be applied on a much wider scale than only tourism companies.
Furthermore, carbon-offsetting should encompass choices. Tourists should be able to choose between different options of how they want to offset their emissions, e.g. via simple methods like tree-planting, to partially fund sustainability seminars for local kindergartens, or partially fund large scale green energy developments. Carbon offsetting has become quite popular among airlines (e.g. Icelandair) and many travel agencies. This is certainly a step in

the right direction but it is at risk of being a tool for only those who are sufficiently financially well off to soothe their conscience rather than being applicable to all tourist types.

It is positive to see that that environmental management systems (EMS) do make a difference, for example in the accommodation sector and possibly in the activities/attractions sector. However, their possible contribution is very limited due to a low volume in comparison to the overall emissions, since the burning of fossil fuels for various transportation modes is the single largest contributor. If any real results in mitigation are to be seen, another source of energy needs to enter the field of global transportation methods for tourism. It will probably be some time before we see electric passenger planes in the skies, but electric vehicles are already a tangible reality where constant developments and improvements are being made for the benefit of the consumer and the environment. This development could be an opportunity for Iceland. For example Höldur, through their car rental company *Europcar* (Steingrímur Birgisson 2010) has already taken the first step and added an electric vehicle to its fleet. This idea could be beneficial for Iceland, e.g. to change all its rental car fleet (or preferably total car fleet) into electric cars which would benefit the environment and could also be promoted on a global scale. Iceland has an advantage compared to so many other countries due to its clean energy, vast expanse of nature and unusual landscape in a relatively unpopulated country. It could put Iceland in the front seat of green destination places and possibly put Iceland in an enviable position by making it independent from imported fossil fuels – domestic energy would perhaps be sufficient. To spend your vacation in "fresh" Iceland could possibly come close to levelling out the total CF for many tourists due to their long-haul flights or relatively short cruise.

The demand factor must become more forceful among tourists themselves and their individual choices of transportation modes is the part where they can influence their emissions more directly. Despite low consumption tourists' efforts to be spendthrift (and perhaps environmentally friendly) in their domestic transportation choices, international transportation choices outweigh all of the possible mitigation efforts undertaken.

Furthermore, the detailed documentation of various operations demanded in an EMS would help to improve the data acquisition substantially when another attempt will made to measure the CF of foreign tourists in Iceland. Even a detailed analysis of the individual sectors (transportation, accommodation and attractions/activities) would help tremendously in order to get a clear perspective of the industry.

As previously stated, a research venture like this has not been conducted before in Iceland but it will hopefully be a benchmark in CF analysis of tourists in Iceland.

The main flaw of this analysis is lack of data in all fields in order to make it more robust. Information is important and therefore it is further emphasised that the tourism industry must monitor its behaviour and report it somewhere, which is where the Icelandic Environmental Agency should be a leading agency with the Icelandic Tourist Board. Furthermore, this study lacks comparative data since so many researches on small islands calculate GHG (thus indicating results in CO_2-eq). A gap is left for others to continue and calculate the overall CO_2 emission (or GHG) from tourists in Iceland, where all three scopes should be incorporated, encompassing water, waste, food, imports etc. For that, a tailor made survey or detailed interviews are suggested.

Pollution and other negative environmental effects are one side of the tourism industry – a local behaviour that can have an environmental consequence on both a local and global scale. It is not the purpose of this research to downgrade the tourism industry or discourage it, but rather the opposite – to encourage it to constantly seek ways to improve its "method of production" i.e. provide a tourist experience in full harmony with nature. If the tourism industry in Iceland would adopt the information provided here on the environmental cost that follows tourism and seek ways to change their methods in order to reduce their CF, it would probably benefit them in the long run, i.e. with social, economical and environmental effects in mind. In relation to the brief discussion about carrying capacity of Iceland it is not the purpose of this thesis to make any assumptions concerning that. Nonetheless, the Icelandic government (e.g. its environmental policy) and the tourism industry as a whole needs to start contemplating on this issue. Carbon footprint could be one of the factors analysed in that discussion. During the preparation of this research it continuously came up for discussion that under current circumstances the threshold is dangerously close and a lack of direction and long-term planning in terms of tourism is perceived. Sustainability in tourism would be honourable and tourism companies should work together towards that noble goal – to offer “fresh tourism”. The consumer group that consists of green consumers is gradually becoming larger and its demands are simple: sustainability and responsible environmental behaviour.

References

Associated Icelandic Ports (2013). Minnisblað um umferð og viðskipti farþega skemmtiferðaskipa á Skarfabakka [Memorandum of traffic and business of cruise ship passengers on Skarfabakki port]. Issued September 17th 2013. Retrieved from http://www.faxafloahafnir.is/wp-content/uploads/2013/10/minnisblad_fyrir_hafnarstjorn_um_skemmtiferdaskip_a_skarfabakka_04.pdf

AEA (2014). The Association of European Airlines. Research and Statistics. Industry QandA´s. Retrieved March 28th 2014 from http://www.aea.be/research/qas/

Árni Ragnarsson (2010). *Geothermal Development in Iceland 2005-2009*. Proceedings World Geothermal Congress 2010. Bali, Indonesia, 25-29 April 2010. Retrieved April 10th 2014 from http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0124.pdf

Baldvinsson, Ívar; Þórisdóttir, Þóra H.; Ketilsson, Jónas (2011). *Gaslosun jarðvarmavirkjana á Íslandi 1970-2009.* Reykjavík. *Orkustofnun* [*Gas emissions from geothermals power plants in Iceland 1970-2009*. Reykjavík. *National Energy Authority*]. Retrieved from http://www.os.is/gogn/Skyrslur/OS-2011/OS-2011-02.pdf

Ban Ki-moon (2007). *Secretary-General´s remarks at World Tourism Organization Headquarters.* United Nations. Latest Statements. Madrid, Spain, 5 June 2007 – Retrieved March 14th 2014 from http://www.un.org/sg/statements/?nid=2603

Bayar, A. and Mc Morrow; K. (1999). Determinants of private consumption. European Commission. *European Economy – Economic papers. 135*, p.32. May 1999, Brussels. Retrieved April 6th 2014 from http://ec.europa.eu/economy_finance/publications/publication_summary11177_en.htm

Bayer, Peter; Rybach Ladislaus; Blum, Philipp; Brauchler, Ralf (2013). Review on life cycle environmental effects of geothermal power generation. *Renewable and Sustainable Energy Reviews 26*, 446-463.

Becken, Susanne and Patterson, Murray (2006). Measuring National Carbon Dioxide Emissions from Tourism as Key Step Towards Achieving Sustainable Tourism. *Journal of Sustainable Tourism, 14* (4), 323-339. Doi: 10.2167/jost547.0

Bourse, Loïc (2011). Profile of sustainability in some Mediterranean tourist destinations. Synthesis: Torremolinos, Spain. Based on the case study by Enrique Navarro Jurado. Plan Bleu. *UNEP/MAP Regional Activity Centre*, September 2011. Retrieved from http://planbleu.org/sites/default/files/publications/3-6-en_synthesetorremolinos.pdf

British Columbia (2013). *B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions. Including Guidance for Public Sector Organisations, Local Governments and Community Emissions.* Victoria, B.C.; Ministry of Environment. December 2013. Retrieved January 12th 2014 from http://www.env.gov.bc.ca/cas/mitigation/pdfs/BC-Best-Practices-Methodology-for-Quantifying-Greenhouse-Gas-Emissions.pdf

Butler, Richard (1980). The concept of tourism area cycle of evolution: implications for management of resources. *Canadian Geographer* 24 (1), 5-12.

Carbon Neutral Calculator (2012). *Calculations and Emission Factors*. Posted May 12th 2012. Retrieved from http://www.carbonneutralcalculator.com/Carbon%20Offset%20Factors.pdf

CBI (2013). Aviation and Marine fuel Systems. *Oil Conversion Factors*. Updated 2013. Retrieved March 29th 2014 from http://www.cbi.dk/conversion.html

Central Bank of Iceland (2014). Exchange rate. Latest fixing April 11th 2014. Retrieved April 11th 2014 from http://www.cb.is/exchange-rate/

Chan, Man-Kwun (2009). *Carbon Management – A Practical Guide for Suppliers*. Supplier Support and Information Initiative. University of Cambridge, Programme for Sustainability Leadership.

Chandler, William; Schaeffer, Roberto; Dadi, Zhou; Shukla, P.R.; Tudela, Fernando; Davidsson, Ogunlade; Alpan-Atamer, Sema (2002). Climate Change Mitigation in developing Countries. Brazil, China, India, Mexico, South Africa and Turkey. PEW Center. Retrieved from http://www.c2es.org/docUploads/dev_mitigation.pdf

Convertit.com (2002). *Measurement Converter*. Retrieved March 27th 2014 http://www.convertit.com/Go/ConvertIt/Measurement/

CO_2Now (2014). CO_2Now.org – CO_2 Home – *Atmospheric CO_2 for July 2014. Preliminary monthly average as of August 6th, 2014*. Retrieved August 20th 2014 from http://co2now.org/

De Bruijn, Kim; Dirven, Rob; Eijgelaar, Eke; Peeters, Paul (2012). *Travelling large in 2012 – The carbon footprint of Dutch holidaymakers in 2012 and development since 2002*. NHTV Centre for Sustainable Tourism and Transport in collaboration with NRIT Research and NBTC-NIPO Research. NHTV Breda University of Applied Sciences, Netherlands.

DEFRA (2009). Department for Environment Food and Rural Affairs. *Guidance on how to measure and report your greenhouse gas emissions.* London. Retrieved March 11th 2014 from https://www.gov.uk/government/publications/guidance-on-how-to-measure-and-report-your-greenhouse-gas-emissions

DEFRA (2012). Department for Environment Food and Rural Affairs. *2012 Guidelines to DEFRA/DECC´s GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors.* London, July 2012. Retrieved March 12th 2014 from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69568/pb13792-emission-factor-methodology-paper-120706.pdf
tables also provided in an older version, May 2012. Retrieved March 16th 2014 from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69554/pb13773-ghg-conversion-factors-2012.pdf

Delta (2014). Delta Airlines. *Aircraft - Boeing 757-200 (75N)*. Retrieved March 26th 2014 from http://www.delta.com/content/www/en_US/traveling-with-us/airports-and-aircraft/Aircraft.html

Dwyer, Larry; Forsyth, Peter; Spurr, Ray; Hoque, Serajul (2010). Estimating the carbon footprint of Australian tourism. *Journal of Sustainable Tourism*, *18 (3)*, 355-376. DOI: 10.1080/09669580903513061

EAI (2013). Environmental Agency of Iceland. *Emissions of greenhouse gases in Iceland from 1990-2011*. National Inventory Report 2013. Retrived May 23rd 2014 from http://www.ust.is/library/Skrar/Atvinnulif/Loftslagsbreytingar/ICELAND%20NIR%202013%20-%20Copy%20(1).pdf

ECCE (2013). Energy Conversion Congress & Expo. *ECCE Europe 15th European Conference on Power Electronics and Applications*. 3-5 September 2013. Retrieved from http://www.epe2013.com/index.php?page=how-carbon-emission-is-computed

European Commission (2014). European Commission. Climate Action. *Reducing Emissions from aviation*. Updated March 12th 2014. Retrieved from http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm

European Commission, Food and Agriculture Organisation, International Monetary Fund, Organisation for Economic Cooperation and Development, United Nations, World Bank (2012). *System of Environmental-Economic Accounting – Central Framework.* Retrieved March 2nd 2014 from http://unstats.un.org/unsd/envaccounting/White_cover.pdf

Eagle Air (2012). Eagle Air Iceland. Adventure Tours. Retrieved February 19th 2014 from http://www.eagleair.is/adventure

Eurostat, OECD, UN, UNWTO (2001). United Nations World Tourism Organisation. *Tourism Satellite Account: Recommended Methodological Framework*. Eurostat, OECD, WTO, UNSD, 2001, paras 1.1and 2.1. Retrieved from http://unstats.un.org/unsd/publication/SeriesF/SeriesF_80e.pdf

Eurostat (2013). European Commission – Eurostat. Passanger Transport Statistic. *Table 1. Modal split of inland passanger transport, 2001 and 2011 (1) (% of total inland passenger-km*. Issued October 2013. Last modified March 12th 2014. Retrieved from http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Passenger_transport_statistics#Road_passengers

FCCC (2009). Framework Convention on Climate Change. *Potential costs and benefits of adaptation options: A review of existing literature*. December 7th 2009.

Filimonau, Viachaslau; Dickinson, Janet; Robbins, Derek; Reddy, Maharaj Vijay (2013). The role of ´indirect´greenhouse gas emissions in tourism: Assessing the hidden carbon impacts from a holiday package tour. *Transportation Research*, Part A (54), 78-91.

Forest Carbon Group (2014). *Forest Carbon Group – More Forest, More Value. Services - Offset your carbon footprint now. How is it calculated?* Retrieved July 14th 2014 from http://www.forestcarbongroup.de/carbon_calculator/fcg/web/uploads/assets/en/_Flights.pdf

Forsyth, Peter; Hoque, Serajul; Dwyer, Larry; Spurr, Ray; Ho, Thiep Van; Pambudi, Daniel (2008). *The Carbon Footprint of Australian Tourism*. CRC for Sustainble Tourism Pty Ltd. Retrieved January 8th 2014 from http://www.sustainabletourismonline.com/1008/climate-change/the-carbon-footprint-of-australian-tourism

GFN (2012). Global Footprint Network. *Footprint Basics – Overview*. Updated July 18th 2012. Retrieved February 5th 2014 from http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_basics_overview

GFN (2013). Global Footprint Network. *World Footprint – Do we fit on the planet?* Updated June 17th 2013. Retrieved February 17th 2014 from http://www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/

GHG Protocol (2005). Greenhouse Gas Protocol. *Calculating CO_2 emissions from mobile sources*. Guidance to calculation worksheet. Retrieved from http://www.ghgprotocol.org/files/ghgp/tools/co2-mobile.pdf

Grímur Sæmundsson (2012). *Afkomumet slegin í Bláa lóninu í fyrra* [Record Income for Blue Lagoon last year]. Interview with Grímur Sæmundsson CEO of Blue Lagoon in *Viðskiptablaðið* [Iceland Business Journal]. Posted December 15th 2012. Retrieved March 19th 2014 from http://www.vb.is/frettir/79096/

Gössling, Stefan; Peeters, Paul; Ceron, Jean-Paul; Dubois, Ghislain; Patterson, Trista; Richardsson, Robert B. (2005). The eco-efficiency of tourism. *Ecological Economics*, 54, 417-434.

Gössling, Stefan and Schumacher, Kim Philip (2010). Implementing carbon neutral destination places: issues from the Seychelles. *Journal of Sustainable Tourism, 18 (3)*, 377-391.

Gössling, Stefan (2013). National Emissions from tourism: An overlooked policy challenge? *Energy Policy*, 59, 433-442. Doi.org/10.1016/j.enpol.2013.03.058

Hertwich, Edgar G. and Peters, Glen P. (2009). Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *Environmental Science & Technology, 43 (16)*, 6414-6420.

Hoffmann, Andrew J. (2000). *Competitive Environmental Strategy – A Guide to the Changing Business Landscape*. Island Press, Washington.

Hoque, Serajul; Forsyth, Peter; Dwyer, Larry; Spurr, Ray; Ho, Thiep Van; Pambudi, Daniel (2010). *The Carbon Footprint of Queensland Tourism.* STCRC Centre for Economics and Policy. CRC for Sustainable Tourism Pty Ltd.

Howitt, Olivier J.A.; Revol, Vincent G.N.; Smith, Inga J.; Rodger, Craig J. (2010). Carbon Emissions from International Cruise Ship Passanger´s travel from New Zealand. *Energy Policy 38*, 2552-2560.

IATA (2013). *International Air Transport Association*. Annual Review 2013. Retrieved January 15th 2014 from http://www.iata.org/about/Documents/iata-annual-review-2013-en.pdf

ICAO (2011a). *International Civil Aviation Organisation*. About ICAO. Retrieved from http://www.icao.int/about-icao/Pages/default.aspx

ICAO (2011b). *International Civil Aviation Organisation*. Environmental Protection – Carbon Emissons Calculator. Retrieved March 23rd 2014 from http://www.icao.int/ENVIRONMENTAL-PROTECTION/CarbonOffset/Pages/default.aspx

ICAO (2011c). *International Civil Aviation Organisation*. ICAO Carbon Emissons Calculator – Version 5. Issued June 2012. Retrieved from http://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v5-2012.Revised.pdf

Icelandair (n.d.). *Icelandair Group og Boeing undirrita viljayfirlýsingu* [Icelandair and Boeing sign a memorandum of understanding]. Retrieved April 1st 2014 from http://www.icelandair.is/boeing/

Icelandguest.com (n.d.). Online travel agency. Retrieved March 2nd 2014 from http://www.icelandguest.com/travel-guide/highlights/capital-area/reykjavik/

Icelandic Road Traffic Directorate (2014). Ökutækjaskrá – Uppfletting í ökutækjaskrá [Vehicle registration – Search in vehicle registration]. Retrieved May 23rd 2014 from http://www.samgongustofa.is/umferd/okutaeki/okutaekjaskra/uppfletting?vq=pu791

Iceland National Power (2011). *Landsvirkjun – Umhverfisskýrsla 2011* [Iceland National Power – Environmental Report 2011]. Retrieved March 28th 2014 from http://www.landsvirkjun.is/Media/Umhverfisskyrsla_Landsvirkjunar_2011.pdf

Icestats (2004). Iceland Statistics. *Tourism, transport and information technology – Passangers – Foreign Passangers 1971-1999*. Updated December 12th 2004, retrieved February 4th 2014 from http://www.statice.is/?PageID=1235&src=https://rannsokn.hagstofa.is/pxen/Dialog/varval.asp?ma=SAM02101%26ti=Foreign+passengers+1971-1999++%26path=../Database/ferdamal/Farthegar/%26lang=1%26units=Number/percent

Icestats (2012). Statistics Iceland. *Geography and Environment. Gas emissions. Greenhouse gas emissions by source 1990-2010 – Total man-made emissions whitout carbon sequestration.* Last updated November 6th 2012. Retrieved February 19th 2014 from http://www.statice.is/Statistics/Geography-and-environment/Gas-emission

Icestats (2013a). Statistics Iceland. *Tourism, transport and information Technoloy. Tourist Industry*. Retrieved February 15th 2014 from http://www.statice.is/?PageID=1512&src=https://rannsokn.hagstofa.is/pxen/Dialog/varval.asp?ma=SAM08602%26ti=Export+of+goods+and+service+by+industries+19902010+++%26path=../Database/ferdamal/ferdaidnadur/%26lang=1%26units=Million%20ISK/percent

Icestats (2013b). Statistics Iceland. *Tourism, Transport and information technology. Accommodation. Overnight stays, arrivals and average length of stay in hotels and guesthouses 1998-2012*. Retrieved March 25th 2014 from http://www.statice.is/?PageID=1234&src=https://rannsokn.hagstofa.is/pxen/Dialog/varval.asp?ma=SAM01201%26ti=Overnight+stays%2C+arrivals+and+average+length+of+stay+in+hotels+and+gueasthouses+1998-2012+%26path=../Database/ferdamal/GiHotGist/%26lang=1%26units=Number

Icestats (2014a). Statistics Iceland. *Population – Key figures 1703-2014*. Retrieved June 1st 2013 from http://www.statice.is/?PageID=1170&src=https://rannsokn.hagstofa.is/pxen/Dialog/varval.asp?ma=MAN00000%26ti=Population+-+key+figures+1703-2014+++++++++%26path=../Database/mannfjoldi/Yfirlit/%26lang=1%26units=Number

Icestats (2014b). Statistics Iceland. *External trade. Trade in goods and services. Major items of the exports of goods and services 2009-2013*. Retrieved March 11th 2014 from http://www.statice.is/?PageID=2269&src=https://rannsokn.hagstofa.is/pxen/Dialog/varval.asp?ma=UTA05001%26ti=Major+items+of+the+exports+of+goods+and+services+20092013++++++%26path=../Database/utanrikisverslun/voruthjonusta/%26lang=1%26un its=Million%20ISK

IEA (2013). International Energy Agency. *2013 Key World Energy Statistics.* Retrieved January 18th 2014 from http://www.iea.org/publications/freepublications/publication/name,31287,en.html

IMO (2005). International Maritime Organisation. *Interim Guidelines for Voluntary Ship CO_2 Emission Indexing For Use In Trials.* MEPC/Circ.471, Issued July 25th 2005. Retrieved from http://www.imo.org/blast/blastDataHelper.asp?data_id=12740&filename=471.pdf

IMO (2008). International Maritime Organisation. Prevention of Air Pollution from Ships. *Updated 2000 study on Greenhouse Gas Emissions from Ships – Phase 1 Report.* Marine Environment Protection Committee, 58th session, September 1st 2008. Retrieved March 23rd 2014 from http://www.imo.org/blast/blastDataHelper.asp?data_id=26402&filename=INF-6.pdf

IMO (2014a). International Maritime Organisation. *IMO and the Environment*. Posted March 9th 2014. Retrieved March 14th 2014 from http://www.imo.org/OurWork/Environment/Documents/IMO%20and%20the%20Environment%202011.pdf

IMO (2014b). International Maritime Organisation. *Sulphur Oxides (SO_x) – Regulation 14.* Retrieved March 9th from http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx

IMO (2014c). International Maritime Organisation. *Our Work – Marine Environment – Pollution Prevention – Air Pollution and Greenhouse Gas Emissions.* Posted March 9th 2014. Retrieved March 15th 2014 from http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Default.aspx

Ingveldur Geirsdóttir (2014, January 28th). Endurnýja frekar en að fjölga rútunum. *Morgunblaðið.* [Renew rather than adding more buses. *The Morning Paper*]. Retrieved from http://www.mbl.is/frettir/innlent/2014/01/28/endurnyja_frekar_en_fjolga_rutunum/

IRCA (n.d.). The Icelandic Road and Coastal Administration. *Vegakerfið – Vegalengdir* [*The Road System – Distances*]. Retrieved March 20th 2014 from http://www.vegagerdin.is/vegakerfid/vegalengdir/

ITB (2012). Icelandic Tourism Board. *Numbers and Publishings – Surveys and Researchs – Travel Behaviour of foreign Tourists. Survey among foreign tourists in Iceland, summer 2011.* Retrieved January 8th 2014 from http://www.ferdamalastofa.is/is/tolur-og-utgafur/kannanir-og-rannsoknir/ferdavenjur-erlendra-ferdamanna

ITB (2013). Icelandic Tourism Board. *Fjármögnun uppbyggingar og viðhalds ferðamannastaða – Yfirlit yfir gjaldtökuleiðir* [Financing the development and maintenance of tourist attractions - Overview of possible tariff methods]. Authors; Árni Geirsson and Kristín Rós Jóhannesdóttir. Produced by Alta ehf. for the Ministry of Industries and Innovation.

ITB (2014). Icelandic Tourism Board. *Research & Statistics. Tourism in Iceland in Figures.* Published April 2014. Retrieved May 11th 2014 from http://www.ferdamalastofa.is/en/recearch-and-statistics/tourism-in-iceland-in-figures

IPCC (1996). International Panel on Climate Change. *Guidelines for National Greenhouse Gas Inventories: Reference Manual. Volume 3. Revised.* Retrieved February 2nd 2014 from http://www.ipcc-nggip.iges.or.jp/public/gl/invs6a.html

IPCC (2006). International Panel on Climate Change. *Guidelines for National Greenhouse Gas Inventories. Chapter 3: Mobile Combustion*. Retrieved February 2nd 2014 from http://www.ipcc-nggip.iges.or.jp/public/2006gl/

Íslandsbanki (2012). *Íslenski orkumarkaðurinn.* September 2012 [Bank of Iceland. The Icelandic Energy Market]. Issued September 2012]. Retrieved from http://www.islandsbanki.is/library/Skrar/Geothermal-Reports/%C3%8Dslenski-Orkumarka%C3%B0urinn-Skyrlsa.pdf

Jones, Calvin and Munday, Max (2007). Exploring the Environmental Consequences of Tourism: A Satellite Account Approach. *Journal of Travel Research*, 46 (164), 163-172. DOI: 10.1177/0047287507299592.

Jónsdóttir, Ásdís (2012). University of Iceland - Institute for Sustainability Studies. *Adapting to climate change, Coast Adapt*. Report. Retrived April 10th from http://stofnanir.hi.is/ssf/sites/files/ssf/Adapting%20to%20climate%20change%20in%20Iceland.pdf

Justgreen (2014). *JustGreen Lifestyle by Just Energy*. *Carbon Offsetting*. Retrieved February 9th 2014 from http://www.justgreencommunity.com/carbon-emission-calculator/

Kelly, Joe and Williams, Peter W. (2007). Modelling Tourism Destination Energy Consumption and Greenhouse Gas Emissions: Whistler, British Columbia, Canada. *Journal of Sustainable Tourism*, *15* (1).

Larsen, Hogne N. and Hertwich, Edgar G. (2009). The Case for consumption-based accounting af greenhouse gas emissions to promote local climate action. *Environmental Science & Policy*, *12*, 791-798.

McDonough, William and Braungart, Dr. Michael (2002). Design for the Triple Top Line: New Tools for Sustainable Commerce. *Corporate Environmental Strategy*, *9* (3).

Minx, J.C; Wiedmann, T; Wood, R; Peters, G.P; Lenzen, M; Owen, A; Scott, K; Barrett, J; Hubacek, K; Baiocchi, G; Paul, A; Dawkins, E; Briggs, J; Guan, D; Suh, S; Ackerman, F (2009). *Economics Systems Research*, *21* (3), 187-216. DOI: 10.1080/09535310903541298.

Munday, Max; Turner, Karen; Jones, Calvin (2012). Accounting for the carbon associated with regiona consumption. *Tourism Management*, *36*, 35-44.   .

National Energy Authority (2012). *Orkutölur 2012* [Energy Statistics 2012]. Retrieved from http://www.os.is/gogn/os-onnur-rit/orkutolur_2012-   islenska.pdf

National Museum of Iceland (2012). *Ársskýrsla 2012* [Annual Report 2012]. Reykjavik, National Museum. Retrieved from http://www.thjodminjasafn.is/media/utgafa/Arsskyrsla-2012.pdf

Niras (2011). NIRAS Gruppen A/S. *Climate Change – Carbon Footprint Analysis*. Website last updated March 30th 2011. Retrieved from http://www.niras.com/Themes/Climate-change/Carbon-Footprint-Analysis.aspx

OECD (n.d.). Organisation for Economic Co-Operation and Development. *Gross Domestic Product of Iceland.* Retrieved June 2nd 2014 from http://stats.oecd.org/index.aspx?queryid=9185

Oilsandreview.com (n.d.). Oilsandsreview – The Heavy Oil Authority. *Energy Toolkit, Conversion Factors.* Retrieved March 22nd 2014 from http://www.oilsandsreview.com/common/convs.asp

Ólafsdóttir, Rannveig (2012). The Reykjavik Grapevine. *Travellers Take Their Toll on Tourist Destination – Are you loving Iceland to death*. Atli Arnarsson, issued July 5th 2012. Retrieved from http://www.grapevine.is/Features/ReadArticle/Travellers-Take-Their-Toll-On-Tourist-Destinations

Óskar Stefánsson (2011, June 28th). *Flugið ódýrara en rútuferð* [To fly cheaper than by bus]. Interview in Fréttablaðið [domestic newspaper]. Retrieved March 23rd 2014 from http://timarit.is/view_page_init.jsp?pageId=5154842

Patterson, Murray and McDonald, Garry (2004). How Clean and Green is New Zealand Tourism? Lifecycle and Future Environmental Impacts. *Landcare Research Science Series*, 24. Lincoln, Canterbury, New Zealand.

Perch-Nielsen, Sabine; Sesartic, Ana; Stucki, Matthias (2010). The greenhouse gas intensity of the tourism sector: The case of Switzerland. *Environmental Science & Policy*, 13, 131-140. DOI: 10.1080/0953531090354129.

Peters, Glen P. og Hertwick, Edgar G. (2006). Post-Kyoto greenhouse gas inventories: production versus consumption. *Climate Change, 86*, 51-66. DOI 10.1007/s10584-007-

Registers Iceland (n.d.). *Property registers*. Retrieved March 25th 2014 from http://www.skra.is/fasteignaskra/

Road Traffic Directorate (n.d.,a). *Meðalaldur bifreiða – 2011* [Average age of vehicles - 2011]. Retrieved March 19th 2014 from http://ww2.us.is/node/639

Road Traffic Directorate (n.d.,b). *Allar hópbifreiðar – 2011* [All Coaches – 2011]. Retrieved March 22nd 2014 from http://ww2.us.is/node/612

Rockström, Johan; Steffen, Will; Noone, Kevin; Persson, Åsa; Chapin, F. Stuart III; Lambin, Eric; Lenton, Timothy M.; Scheffer, Marten; Folke, Carl; Schellnhuber, Hans Joachim; Nykvist, Björn; de Wit, Cynthia A.; Hughes, Terry; van der Leeuw, Sander; Rodhe, Henning; Sörlin, Sverker; Snyder, Peter K; Costanza, Robert; Svedin, Uno; Falkenmark, Malin; Karlberg, Louise; Corell, Robert W.; Fabry, Victoria J.; Hansen, James; Walker, Brian; Liverman, Diana; Richardson, Katherine; Crutzen, Paul; and Foley; Jonathan,. (2009). *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*. *Ecology and Society*, *14* (2). Retrieved September 20th 2012. http://www.ecologyandsociety.org/vol14/iss2/art32/

RUV (2012). *Vilja herða eftirlit með bílaleigum*. Ríkissjónvarpið [Want to tighten surveillance with car rentals. Icelandic National Broadcasting]. Posted July 10th 2012. Retrieved from http://www.ruv.is/frett/vilja-herda-eftirlit-med-bilaleigum

SAF (2013). The Icelandic Tourist Industry Association. *Yfir 10 ára meðalaldur bílaleigubíla hjá tæplega 17% bílaleiga* [Average age of rental cars is over 10 years with approximately 17% of car rentals]. Posted August 22nd 2013. Retrieved from http://www.saf.is/allar-frettir/

Steingrímur Birgisson (2010, October 15th). Europcar tekur rafbíla í notkun á næstuni. *Morgunblaðið* [Europcar will soon take electric cars into its service. *The Morning Paper*]. Retrieved from http://www.mbl.is/mm/mogginn/blad_dagsins/bl_grein.html?grein_id=1352544

STF (2012). Shrink That Footprint. *What is a Carbon Footprint?* Updated November 15th 2012. Retrieved March 4th 2014 from http://shrinkthatfootprint.com/what-is-a-carbon-footprint

Simpson, M.C., Gössling, S., Scott, D., Hall, C.M. and Gladin, E. (2008). *Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices.* UNEP, University of Oxford, UNWTO, WMO: Paris, France.

Sims, R.E.H. R.N. Schock, A. Adegbululgbe, J. Fenhann, I. Konstantinaviciute, W. Moomaw, H.B. Nimir, B. Schlamadinger, J. Torres-Martínez, C. Turner, Y. Uchiyama, S.J.V. Vuori, N. Wamukonya, X. Zhang, (2007). Energy supply. In *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf

Sisman, Dick and Associates (2007). *Carbon Footprint of Destinations*. Retrieved December 28th 2013 from http://www.thetravelfoundation.org.uk/images/media/7._Carbon_footprint_calculation_guide.pdf
Smyril Line (n.d.,a). Smyril Line. *Info about the ship. Welcome aboard.* Retrieved March 18th 2014 from http://www.smyrilline.com/Info-about-the-ship-11817.aspx
Smyril Line (n.d.,b). Smyril Line. *The Journey*. Retrieved March 18th 2014 from http://www.smyrilline.com/The-Journey-11407.aspx
T&E (2013). Transport and Environment. *Mind the Gap! Why Official car fuel economy figures don´t match up to reality*. Ed. Joe Dings. Published March 2013 by T&E Brussels. Retrieved January 30th 2014 from http://www.transportenvironment.org/sites/te/files/publications/Real%20World%20Fuel%20Consumption%20v15_final.pdf
TNAU (2013). Tamil Nadu Agricultural University. *Environment & Pollution: Introduction. Pollution, Definition*. Retrieved January 12th 2014 from http://www.agritech.tnau.ac.in/environment/envi_pollution_introduction.html
Torchbox (2008, March). *Carbon calculation methodology*. The carbon account. Retrieved from http://www.thecarbonaccount.com/static/files/full_explanation.pdf
Trex.is (2010). TREX – Travel Experiences. *Full Circle Passport*. Retrieved March 9th 2014 from http://en.trex.is/?c=webpage&id=48&lid=39&pid=24&option=links
UN (1987). United Nations. Our Common Future. *Report of the World Commission on Environment and Development.* Retrieved from http://www.un-documents.net/our-common-future.pdf
UN (1998). United Nations. *Kyoto Protocol to the United Nations Framework Convention on Climate Change.* Retrieved from https://unfccc.int/kyoto_protocol/items/2830.php
UNECE (n.d.). United Nations Economic Commission for Europe. *Convention on Long-range Transboundary Air Pollution*. Retrieved March 15th 2014 from http://www.unece.org/env/lrtap
UNEP (n.d). United Nations Environmental Program. *Business, Cleaner and Safer Production – Related Concepts.* Retrieved February 3rd 2014 from http://www.unep.org/resourceefficiency/Business/CleanerSaferProduction/ResourceEfficientCleanerProduction/UnderstandingRECP/RelatedConcepts/tabid/78838/Default.aspx
UNEP (2003a) – United Nations Environmental Program. Business, Sectoral Activities, Tourism, Facts and Figures about Tourism, Impacts of Tourism, Environmental impacts, *Tourism Three Main Impact Areas.* Retrieved February 4th 2014 from http://www.unep.org/resourceefficiency/Business/SectoralActivities/Tourism/TheTourismandEnvironmentProgramme/FactsandFiguresaboutTourism/ImpactsofTourism/EnvironmentalImpacts/TourismsThreeMainImpactAreas/tabid/78776/Default.aspx
UNEP (2003b) – United Nations Environmental Program. Business, Sectoral Activities, Tourism, Facts and Figures about Tourism, Impacts of Tourism, Environmental Impacts. Retrieved February 3rd 2014 from http://www.unep.org/resourceefficiency/Business/SectoralActivities/Tourism/FactsandFiguresaboutTourism/ImpactsofTourism/EnvironmentalImpacts/tabid/78775/Default.aspx
UNEP and UNWTO (2005). United Nations Environmental Program and World Tourism Organisation. *Making Tourism More Sustainable – A Guide for Policy Makers*. P.2 Retrieved February 3rd 2014 from http://www.unep.fr/shared/publications/pdf/DTIx0592xPA-TourismPolicyEN.pdf

UNEP (2009). United Nations Environmental Program. *The Environmental Food Crisis. The Environment´s Role in Averting Future Food Crisis*. A UNEP Rapid Response Assessment. Retrieved from http://www.grida.no/files/publications/FoodCrisis_lores.pdf

UNFCC (2006). United Nations Framwork Convention on Climate Change. *Conference of the Parties Serving as the Meeting of the Parties to the Kyoto Protocol on it first session, held at Montreal from 28 November to 10 December 2005.* Issued 30 March 2006. Retrieved from http://unfccc.int/kyoto_protocol/background/items/2879.php

UNFCCC (2013). United Nations Framework Convention on Climate Change. *Kyoto Protocol.* Retrieved from http://unfccc.int/kyoto_protocol/items/2830.php

UNFCCC (2014). United Nations Framework Convention on Climate Change. *Emissions from fuel used for international aviation and maritime transport (international bunker fuels)*. Retreived from http://unfccc.int/methods/emissions_from_intl_transport/items/1057.php

UNSD (2008, February). United Nations Statistical Commission. Department of Economic and Social Affairs. *2008 Tourism Satellite Account: Recommended Methodological Framework*. Retrieved from http://unstats.un.org/unsd/publication/Seriesf/SeriesF_80rev1e.pdf

UNWTO (2011, December). United Nations World Tourism Organisation. *Tourism and Climate Change.* Retrieved from http://dtxtq4w60xqpw.cloudfront.net/sites/all/files/docpdf/climatechange.pdf

UNWTO (2012a). United Nations World Tourism Organisation. *Understanding Tourism: Basic Glossary*. Retrieved February 3rd 2014 from http://media.unwto.org/content/understanding-tourism-basic-glossary

UNWTO (2012b). United Nations World Tourism Organisation. *Tourism and the Millennium Development Goals*. Leaflet posted April 12th 2012. Retrieved from http://icr.unwto.org/content/tourism-millennium-development-goals-mdgs

UNWTO (2013). United Nations World Tourism Organisation. *Tourism Highlights. 2013 Edition*. Retrieved from http://dtxtq4w60xqpw.cloudfront.net/sites/all/files/pdf/unwto_highlights13_en_lr_0.pdf

UNWTO (2013, July). United Nations World Tourism Organisation. *About UNWTO.* Retrieved from http://dtxtq4w60xqpw.cloudfront.net/sites/all/files/docpdf/fichaaboutunwtoennomarc.pdf

UNWTO (2014, January). United Nations World Tourism Organisation. *World Tourism Barometer.* Retrieved from http://dtxtq4w60xqpw.cloudfront.net/sites/all/files/pdf/unwto_barom14_01_jan_excerpt.pdf

UNWTO-UNEP-WMO (2008, July). United Nations World Tourism Organisation, United Nations Environment Programme, World Meteorological Organization. Second International Conference on Climate Change and Tourism. *Climate Change and Tourism: Responding to Global Challenges*. United Nations World Tourism Organization and the United Nations Environment Programme. Retrieved from http://www.unep.fr/scp/publications/details.asp?id=WEB/0142/PA

US Department of Energy (2014). Energy efficiency and Renewable Energy. Fuel economy by model. Retrieved from https://www.fueleconomy.gov/feg/bymodel/2010MakeList.shtml

UST (2014). Umhverfisstofnun. *Rauði listinn – Svæði í hættu. Yfirlit til umhverfis- og auðlindaráðuneytis* [The Environment Agency of Iceland. Red list – Endangered areas. Overview for environmental and natural resources administration]. Retrieved August 11th 2014 from http://ust.is/library/Skrar/Einstaklingar/Nattura/Skyrslur/raudi_listinn_2014.pdf

Viðskiptablaðið (2012, December 31st). Nærri 8.000 nýir bílar seldir á árinu [Business Paper. Nearly 8,000 cars sold during the year]. Retrieved from http://www.vb.is/frettir/79392/

Waddington, Glen (2009). *Car Magazine*. Ford Fiesta Econetic (2009) Car review. Posted February 9th 2009. Retrieved March 29th 2014 from http://www.carmagazine.co.uk/Green-Cars/Search-Results/Drives/Ford-Fiesta-Econetic-2009-CAR-review/

Welling, Jóhannes T. (2013). Icelandic Tourism Research Centre. *Tourism, Landscapes and Climate Change in Iceland.* Akureyri. November 2013. Retrieved July 15th 2014 from http://www.rmf.is/files/pdf/skyrslur/2013/Tourism_Landscapes_and_Climate_Change_in_Iceland.pdf

Whittlesea, Emma Rachel and Owen, Anne (2012). Towards a low carbon future – the development and application of REAP Tourism, a destination footprint and scenario tool. *Journal of Sustainable Tourism, 20* (6), 845-865. DOI:10.1080/09669582.2012.680699

Wiedmann, Thomas (2009). Editorial: Carbon Footprint and Input-Output Analysis – An Introduction. *Economic Systems Research, 21*(3), 175-186. Retrieved from http://wenku.baidu.com/view/eeeb01d13186bceb19e8bb33.html

Wiedmann, T. and Minx, J. (2008). A Definition of ´Carbon Footprint´. In: C.C. Pertsova, *Ecological Economics Research Trends*, Ch. 1, (pp.1-11). Nova Science Publishers, Hauppauge NY, USA. Retrieved from http://www.researchgate.net/publication/252489707_A_Definition_of_'Carbon_Footprint/file/60b7d52b42ae1d9583.pdf.

Wood, Richard and Dey, Christopher J. (2009). Australia´s Carbon Footprint. *Economic Systems Research*, *21*(3), 243–266. doi: 10.1080/09535310903541397

Worldwatch (2013). Worldwatch Institute. Vision for a Sustainable World. The State of Consumption Today. Updated April 15th 2014. Retrieved from http://www.worldwatch.org/node/810

Wright, L., Kemp, S., Williams, I. (2011) 'Carbon footprinting': towards a universally accepted definition. *Carbon Management*, *2* (1), 61-72. Doi:10.4155/CMT.10.39

Wu, Weiling (2011). *Carbon Footprint. A Case Study on the Municipality of Haninge.* (Master of Science Thesis in Technology and Health). School of Technology and Health, Stockholm. Retrieved from https://www.kth.se/polopoly_fs/1.193966!/Menu/general/column-content/attachment/Carbon%20Footprint%20-%20A%20Case%20Study%20on%20the%20Municipality%20of%20Haninge.pdf

350.org (2013). What we do. Retrieved July 30th 2014 from http://350.org/about/what-we-do/