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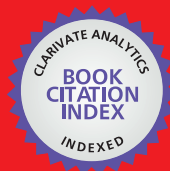
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Pollutants and Greenhouse Gases Emissions Produced by Tourism Life Cycle: Possible Solutions to Reduce Emissions and to Introduce Adaptation Measures

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Additional information is available at the end of the chapter

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1. Introduction

Tourism and Travel (T & T) is a vital contributor to the global economy and considered particularly important for developing countries. It is regarded as an effective way of redistributing wealth and, if conducted according to sustainability directions, may promote cultural heritage conservation and contribute to nature preservation. Tourism industry has experienced a significant development in the last 50 years and, presently, represents around 260 million jobs worldwide, 100 million of whom work directly in the tourism industry and the rest in induced activities. Moreover, tourism accounts for about 9% (direct & induced) of the global GDP [1,2] (more than the automotive industry, 8.5% and slightly less than the banking sector, 11%). The economic and cultural importance of tourism is now widely recognized.

However, negative impacts from tourism may take place, for instance, when the level of visitor use is greater than the capability of the environment to cope with this use, operating beyond the acceptable limits of change or regeneration capacity of a given territory, e.g., by the sheer effect of the number of visitors [3]. A good example is constituted by the Mediterranean coast, where in a narrow strip (50-100 km) about 130 millions of residential habitants are incremented seasonally by about 100 million of tourists. In marine areas tourist activities such as diving or cruising, may cause damage of fragile ecosystems such as coral reefs, which are also affected by CO₂-emissions due to the change in the pH-value of seawater (coral bleaching).

Waste handling and disposal, increment of noise (related mainly to transportation to and at destinations), increased use of water resources [4], loss of biodiversity and wild life habitats by tourism leisure activities, represent part of the stresses put on visited areas, beside the pressure on local resources like energy, food, and other raw materials that might be locally already in short supply.

One of the most negative impacts of tourism is on climate through so-called Greenhouse Gases (GHG) emissions, in particular CO₂ [3,5]. In fact, it is now widely recognized that climate change is a global issue and one of the most serious threats to society, the economy and the environment, being by now for decades a constant issue of concern [6]. The Intergovernmental Panel on Climate Change (IPCC) has reported that warming of the global climate system is unequivocal and that it is likely that anthropogenic GHG production (mainly from energy conversion) have caused most of the observed global temperature rise since the middle of the 19th Century. Hence, ambitious emissions reduction targets for developed countries and an effective framework that addresses the needs of developing countries has been already adopted (e.g., the objectives 20/20/20 in the European Energy Program for Recovery).

Relating these two important issues, it is now recognized that T & T constitutes also a vector of climate change since, according to current estimations, tourism accounts for approximately five per cent of global carbon dioxide emissions, establishing in this way the synergy between T & T and climate, which – on the other side - may define the length and quality of tourism seasons, affect tourism operations, hence attracting or deterring visitors depending on climate conditions. It can be, then, asserted that tourism is a highly climate sensitive economical sector, being of paramount importance the assessment of the possible influence of tourism on climate change through emissions and on environment in general through its implementation.

The principal environmental impact of GHG emissions is climate change but many secondary effects which affect, for instance, coastal areas, have been identified. These are sea surface temperature and sea level rise, changes in temperature and precipitation, as well as biodiversity loss mainly in the marine environment. These changes threaten the quality of destinations, which is at the core of the tourism product. It therefore makes sense for stakeholders in tourism and tourism mobility, not only environmentally but also from the point of view of business, to act more sustainably.

In the tourism sector, energy consumption at destinations and the related GHG emissions strongly depends, e.g., on the infrastructure of the accommodation, particularly installations for heating, cooling and hot water [7]. On the other hand, by definition tourism is impossible without transportation. At destinations the impact of the GHG emissions can be challenged by improving new concepts and/or changing existing infrastructure.

On the other side, for tourism mobility, the type of transport and the distance to be covered determine the amount of energy consumed and, consequently, the emissions generated. Transport to and on destinations represents a high percentage of energy consumption

(currently about 30%), and a large fraction of it is represented by travels for tourism. If we consider that almost all transport vehicles are fuelled by liquid fuels, such as diesel oil, kerosene and gasoline, it appears clear that travels are certainly responsible of large quantities of greenhouse gases emitted into the atmosphere. Hence, for transportation the number of journeys, the distribution over transport modes, total passenger kilometrage travelled, the efficiency of transport means, etc., are the most important parameters to be taken into consideration in assessing emissions.

In this chapter the focus is concentrated on the significant contribution to the emissions of pollutants and greenhouse gases both in the destination and in travels needed to reach the destination and around the destination itself. The approach followed in this analysis is based on the *Life Cycle Assessment* [8], including the effects produced in reaching the destination, the staying in the destination for a certain number of days and travel back to the starting point. The quantification of emissions is performed for different distances between the starting place and the destination, for different period of staying in the destination and for different means of transportation (car, bus, train, ship and airplane). In addition, *Tourism Indicators* [9] are introduced to establish the sustainability level of tourism. Finally, founded on studies and research on the effects produced by pollutants and GHG emissions into the atmosphere, changes that T & T should undergo to improve its sustainability are proposed.

2. Tourism market

Motivations for tourism are multiple; they include: travel, leisure, business, cultural, educational and/or religious purposes. Religion and culture have been key stimulants for many tourist destinations; religious travel has been popular for decades and has allowed for scores of people to take pilgrimages. For example, many Roman Catholics visit the Vatican City annually, while Hindus trek to the Ganges and other spiritual spots across India. Jerusalem and Israel are also popular spots for Christian pilgrims, as well as the Mecca for the Muslims. Due to these reasons, the countries benefit from tourist arrivals and, in many cases, also neighboring countries or cities. Different nations have various histories and unique cultures and traditions that accompany them. The cultural distinctiveness and 'unusual' traditions attract curious or interested travelers to certain places. In addition, if one visits a country for other reasons, the cultural aspects contribute toward a unique experience. The various art forms (song, dance, sculpture and artwork, drama, opera, etc.) and festivities have great influence on visitors' experiences. Often overlapping with other types of tourism, food tourism plays an important part in the industry. Visitors generally prefer sampling local cuisine and many set off on trips to experience food made by locals. As a result, local restaurants and food stands thrive off this. Locals benefit from employment opportunities either directly (servers, cooks and managers for example) or indirectly (e.g., agriculturists and aquaculturists) and the economy of surrounding communities, are boosted.

The economic contribution of tourism has two elements: direct and indirect. The direct contribution is solely concerned with the immediate effect of expenditure made by visitors.

This, for example, accounts for expenditures in hotels, restaurants, souvenir shops, transport services and attractions entrance fees. Indirect contributions are often underestimated: they include, for example, expenditures on fuels for transport and power generation, utility bills for hotels and guest houses (to maintain the electricity and water supply), purchase or rental of equipment for various activities (such as diving, hiking and beach sports), among others.

Tourism in its various forms is currently recognized as the world's largest single industry with a direct worldwide contribution to GDP of about 6% [10]. A world forecasts for the near future estimates a number of international arrivals by the year 2020 of about 1.6 billion.

Figure 1 shows the contribution to the global tourism activities of different geographical areas together with the forecasted increase up to 2020.

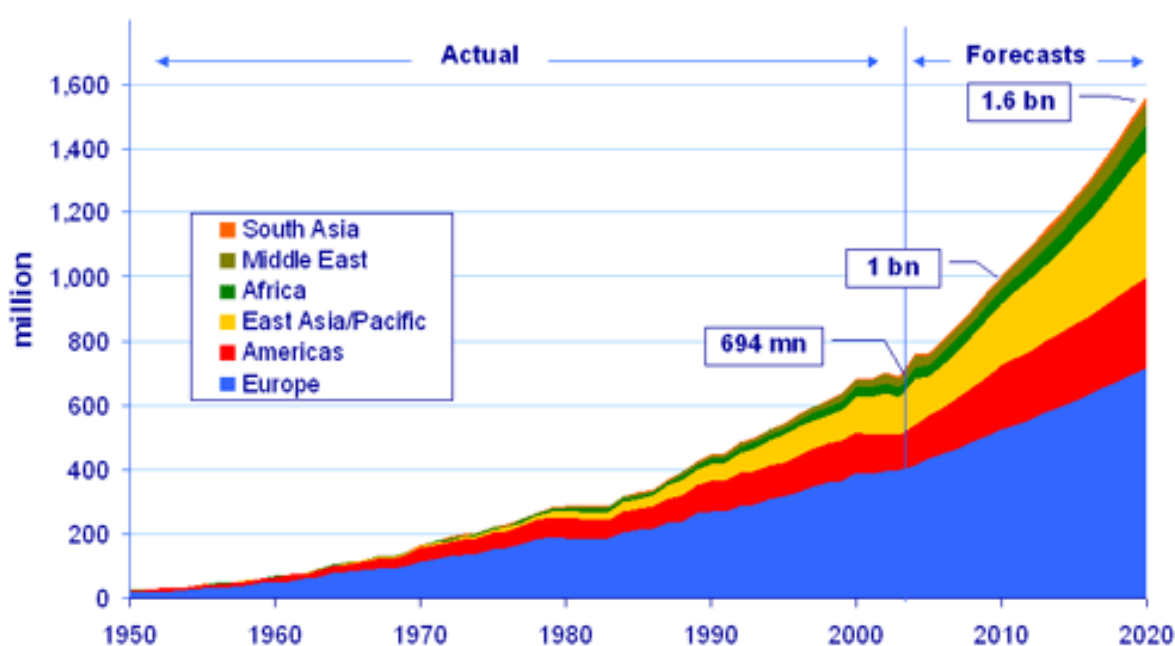


Figure 1. Evolution of world tourism from 1950, in billions of arrivals. Source: [11]

Tourism is one of the strongest economic sectors in the member states of the European Union (EU), where it involves around 2 million businesses (mostly small and medium-sized enterprises) generating up to 12% of the GDP (directly plus indirectly), 6% of employment (directly) and 30% of external trade. All of these figures are expected to further increase as tourism demand is expected to experience a substantial growth. An analysis of changes in tourism in the EU over the past 20 years shows that the numbers of bed-places and overnight stays have increased by almost 64%.

An important sector of tourism is the coastal [12], based on a unique resource combination of the appealing of landscape and sea environment: sun, water, beaches, outstanding scenic views, rich biological diversity (birds, whales, corals, etc.), sea food and good transportation infrastructure. In the middle of the 20th century coastal tourism in Europe turned into mass tourism and became affordable for an increasing portion of the population. Today, more than 60% of the European tourists favor the seashore for vacation. Coastal tourism sector in

Europe is getting increasingly competitive, with tourists expecting increasing quality for lower price [13]. Nowadays tourists expect more than sun, sea and sand, demanding a wide variety of associated leisure activities and experiences, including sports, cuisine, culture and natural attractions. Tourism is becoming more and more important for the economy of the communities at the destinations; it is also a strong employment generator with a total of almost 20 million jobs (direct and indirect employment, in Europe).

Mass tourism is the most common aspect of the industry. It is an assembly of standardized low cost tourism packages appealing to tourism masses traveling to popular geographical areas. It involves tourists on pilgrimages or visiting places of religious interest, tourists visiting beaches or coastal areas, visitors to popular nightlife and casino areas, tourists to popularized landmarks or structural wonders and tourists seeking shopping and leisure in internationally hyped locations.

The growth in world tourism is related to three main factors: increased personal incomes and leisure time; improvements in transportation systems and greater public awareness of other areas of the world due to improved communications. Many destinations have a wealth of assets to give them a distinctive appeal: combinations of activities (leisure activities, sports, cultural and natural heritage, cuisine, etc.); at the same time, local people are increasingly anxious to preserve their own identity, their environment and their natural, historic and cultural heritage, from the impact of unrestrained tourism. In this context, it has been acknowledged that the global tourism industry is a "massive consumer of energy and resources" and, since it is expected to continue to grow significantly in the future, the question of its sustainability has been recognized.

3. Tourism sustainability

3.1. Need for tourism to be sustainable

In the last two decades there has been growing recognition of the importance for tourism to be sustainable. Tourism is one of the oldest industries, it has become integrated into everyday life for many countries and, as discussed in the previous paragraph, is undeniably a major contributor to economic and social development. However, increasing tourist pressure and overexploitation of natural resources endangers the existence of this industry in many countries. In fact, one of the most diffused types, mass tourism, often leads to severe degradation of natural landscapes (e.g., through construction of massive infrastructure), pollution of coastal zones and reduction in water supply. Ecological development with respect to tourism is known as sustainable tourism and it encompasses the development of an industry in such a manner that can sustain itself while improving the quality of life for all concerned stakeholders, such as indigenous populations. Hence, sustainable tourism entails the search for a more productive and harmonious relationship between the visitor, the host community and the residents [14]. In addition, tourism to be sustainable must remain competitive and attract first time as well as reiterate visitors. In this context, recognize, accept and implement limits on tourism development is one way to

counteract the potential overuse and exploitation of destinations natural resources and cultural heritage.

Sustainable tourism (ST) can be, hence, defined as an industry which attempts to make a low impact on the environment and local culture, while aiming to generate income, employment, and the conservation of the local environment. ST should be both, ecologically and culturally sensitive, producing minimum impact on the eco-system and culture of the host community. According to The World Tourism Organization, sustainable tourism is a sort of tourism that leads to the management of all resources in such a way that economic, social and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems. The United Nations Environment Programme (UNEP) refers to the environmental, economic, and socio-cultural aspects of tourism development, and recommends a suitable balance between these three dimensions to guarantee its long-term sustainability [15]. The United Nations World Tourism Organization (WTO) defines ST as an activity that meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future. The objective of ST is, hence, to retain the economic and social advantages of tourism development while reducing or mitigating any undesirable impacts on the natural, historic, cultural or social environment. This can be achieved by balancing the needs of tourists with those of the destination. Summarizing, ST is a tourism that is economically, socio-culturally and environmentally sustainable, with impacts are neither permanent nor irreversible.

3.2. Difficulties and opportunities in making tourism more sustainable

An increasing number of tourists are aware of the environmental impacts that tourism may cause particularly in Europe. They expect a high environmental quality in their destination, usually prefer eco-labeled accommodation services, look for certified products in the travel catalogues and "green" destinations. The direct local impacts of tourism on people and environment at destinations are strongly affected by concentration in space and time (seasonality). There are different quality characteristics requested by tourists, such as clean beaches and water, cleanness in the resorts and in the surrounding areas, reduce urbanization of rural areas, nature protection in the destination, low noise pollution from traffic or discothèques, reduce traffic and good public transport in the destination, possibility of reaching the destination easily by bus or train, environmentally-friendly accommodation, etc. Construction of hotels, recreation and other facilities often leads to increased pressure on sewage facilities, in particular because many destinations have several times more inhabitants in the high season than in the low season. Waste water treatment facilities are often not built to cope with the dramatic rise in volume of waste water during the peak [13]. In some locations, conventional tourism has been accused of failing to integrate its structures with the natural features and indigenous architecture of the destination. One of the most difficult challenges tourism is facing is the ability to combine sound economic development with the protection of natural resources. There will be an increasing need to analyze the trade-offs between native cultural integrity and the benefits

of employment, and the need to understand the impact of rapid climatic changes on prime vacations sites, such as coast lines. Nevertheless, looking at the whole picture it can recognize that tourism can help sustainability. In fact, tourism can facilitate the restoration, conservation and protection of physical environments; it can provide the incentives and the income necessary to restore and rejuvenate historic buildings and to create and maintain national parks. Hence, tourism can be a force for the development of better infrastructure such as improvements to roads, water supply and treatment and waste management systems which can improve environmental quality, facilitating the development of attractions through restoration and protection of natural and built heritage.

3.3. Mobility and sustainability of tourism

The knowledge and proper management of all adverse impacts are extremely important to make tourism sustainable. Generally, they are factors contributing to create environmental pressure exerted locally but not only. For instance, it can be surely asserted that that fuel and electricity consumption in tourism are usually very high, but – as will be discussed below – the travel to reach the destination is the most important contributor to GHG emissions [14]. The approach to sustainability of tourism has been so far concentrated mainly on destination, ignoring that tourism, increasingly oriented toward destinations far away (many thousands km). Therefore fuel consumption and GHG emissions due to mobility have become the most important factors for sustainability assessment.

4. Tourism life cycle

The evaluation or assessment of the “life cycle” of a product or a service in general can be defined as the technique to assess the environmental impact associated with all the phases of the product manufacturing or service provision. The assessment includes all the stages needed to manufacture the product (or delivering the service): extraction of the raw materials, processing, manufacturing of the product itself (or service delivery), distribution, use, maintenances and repair, and – most important – perform its safe disposal or recycling at the end of life. To accomplish the evaluation, the compilation of an inventory of relevant energy and material inputs and environmental releases in each phase has to be performed. Then, the impacts associated with the inputs and releases have to be evaluated and, finally, an interpretation of the results has to be performed with the goal of allowing the decision makers and stakeholders in general to adopt an informed decision [16]. This important process is sometimes also called “Eco balance” and it is also described using the illustrative expression “from the cradle-to-grave”.

The assessment process has been internationally standardized (ISO 14040 and 14044) by including four main phases: goal and scope definition, inventory analysis, assessment of the impacts and, finally, interpretation of the results of the previous phases, as schematically illustrated in *Figures 2 and 3*.

In order to assess tourism activities in terms of environmental effects, the possibility to adopt the LCA process is analyzed. According to the scheme in *Figure 2*, goal definition and

scope could be interpreted as: the goal is the assessment of the environmental impacts of a tourism activity (e.g., a vacation in a destination), whereas the scope is the ideal space in which the touristic activities (travel, permanence, etc.) are performed.

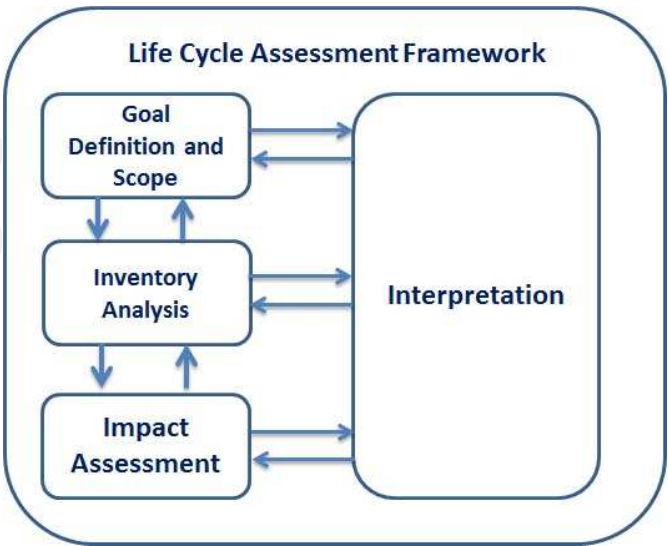


Figure 2. Schematic view of LCA analysis. Source: [16]

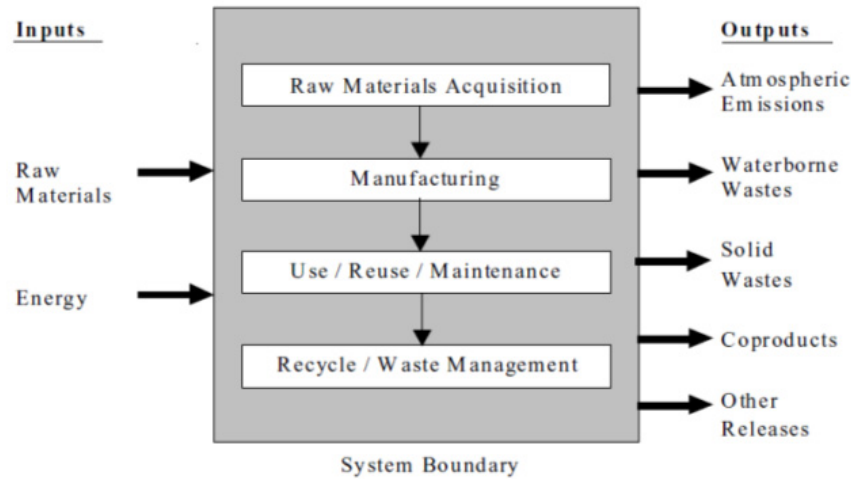


Figure 3. Inventory energy and material. Source: [16]

Before continuing into what would be a life cycle analysis adequate for tourism, it is worthwhile to remember that the concept of tourism life cycle has been already defined in some previous papers. According to [8], tourism life cycle is a six stage model to be performed for the assessment of a destination. It includes the exploration, involvement of the local people, the development of a tourism resort in a given country, the consolidation through the integration of the resort into the local economy, the stagnation (e.g., competition from other resorts, saturation, etc.), and, finally, either the declination or the rejuvenation of the tourism site. This approach, being essentially correct, takes into account only the life cycle of a destination (in this sense, it should be called, tourism area life cycle), without

considering the whole cycle of the most classical tourism activity, the seasonal vacation (reaching the destination, staying and traveling back).

The Butler model is strictly connected to the concept of carrying capacity (CC) of a site; it represents the maximum burden that can be accepted by a territory without producing a crisis of the local ecosystem. WTO has provided a specific definition of tourism CC [17]. [18] defined Tourism Carrying Capacity (TCC) as "...the level of human activity an area can accommodate without the area deteriorating, the resident community being adversely affected or the quality of visitors experience declining". Looking at this definition it appears clear the connection with the Butler model: the stagnation of the area where the tourism is taking place starts when the TCC is reached and the further development is not possible without intervention addressed to a rejuvenation process.

The model proposed in the present paper does not completely fit into the concept contained in the LCA, but has as its ultimate goal the purpose to quantify one of the most important factor, consumption of fossil fuel and related CO₂ and other emissions, mostly produced during travels to reach the destination. The approach implemented in the present paper is an attempt to adopt a methodology able to include all the aspects of a very common type of tourism which consist in a vacation in a destination that can be reached by a traveling round trip.

To make the model operative, identification of the different phases in which pollutant emissions are taking place have to be identified. This type of analysis can be done for different destination and for given data characterizing the period spent in the destination. One valuable approach is the comparison of different ways to spend vacations, trying to select the solution which minimizes the CO₂ emissions. To make the comparison meaningful a functional unit has to be introduced, e.g. the amount of CO₂ emitted for one day spent in vacation (per person in a given place and for a given distance).

On the basis of what has been discussed hitherto, the concept of a vacation life cycle can be schematically defined by the following parameters:

- Number of visitors arriving at a destination and from where.
- Distance from the tourist home to the destination.
- Different scenarios for reaching the final destination (airplane, car, train, bus, ship, etc.).
- Different types of accommodation ranging from camping places, rented homes, mobile homes, mountain huts to five star hotels, if present.
- Number of days staying in the destination.
- Different types of activities that can be performed at the destination, such as diving, sailing, cruises, mobile homes or visiting zoos, cinemas, indoor pools, museums or theatres.
- Mobility in the destination (private car, public transportation, sightseeing tours, etc.).
- Other issues related to the holidays (such as the practice of "zero km" food for catering).

To assess the impacts of all these activities the classical LCA requests the assessment of all the impacts related to the inputs and outputs of the mentioned items. Impacts are

calculated by dividing them into different categories: greenhouse effect (potential global warming), stratospheric ozone depletion, acidification, eutrophication, summer smog, natural resource depletion, aquatic toxicity, etc. The phases of classification, characterization, and interpretation of the results and identification of significant issues are very complicated and it is beyond the scope of this chapter (being its specific purpose the assessment of the GHG emissions) to discuss all the impacts from tourism activities. On the other hand, it is worthwhile to notice that tourism and vacations are often spent in remote destinations and, therefore, large amount of fossil fuels for transportation are requested, hence, to assess, e.g., the contribution of transport on the total impact produced by GHG, the proposed model appears adequate and, hence, considered a valuable approach, able to compare different types of vacation by quantifying the parameters above.

To this goal, the different phases of tourisms related activities generating emissions have to be identified. In the present chapter inventory analysis is limited to the amount of fuel supplied to transportation means, the related CO₂ emissions, neglecting other environmental impacts due to, e.g., maintenance of the carriers.

The evaluation of potential impacts associated with the inputs of tourism life cycle and their related impacts constitutes important information needed for the analysis of the observed and predicted future climate change. In evaluating impact sources it appears clear the paramount influence of the type of transportation means selected. For instance, aviation emissions have a greater climate impact that the same emissions at ground level due to the fact that, at altitude, they can activate a series of chemical and physical processes that can have enhanced consequences on the climate change and have to be taken into account through multiplying factors. By the same token, for automobiles not only their number but also their age and technology, play a paramount role in evaluating emissions.

The outcome of this form of analysis appears useful for a better global managing of tourism and, in general, for making sustainable choices towards a reduction of the atmospheric pollution, limiting CO₂ and other greenhouse gases emissions.

5. Tourism sustainability indicators

In the context of the present chapter it has to be mentioned that indicators are commonly used by organizations to evaluate their success or the success of a particular activity in which they are engaged. Because of their integrative and forward-looking features, Sustainability Indicators (SI) are suitable to measure and evaluate human activities, and more and more businesses, willing to align their activities with the principles of sustainable development, are adopting SI as a powerful tool in addressing a satisfactory development in relationship to the environment.

Some useful indicators to express the level of sustainability of tourism are: carrying capacity, ecological footprint and carbon footprint. The carrying capacity has been already introduced in the previous paragraph.

5.1. Tourism ecological footprint

The Ecological Footprint is a measure of the 'load' imposed by a given population on nature. It represents the land area necessary to sustain a tourism activity in terms of resource depletion and waste discharge by that population [19]. It represents the total area necessary to satisfy all the needs of the population involved in terms of food, water, land, etc. It also includes the large amount of the area necessary to neutralize the effects all the GHGs, e.g., by photosynthesis of plants. This area, (representing the carbon footprint in terms of area, instead in terms of kg of CO₂) results usually very large: the global average amounts at about 50% of the ecological footprint. In the case of long distance tourism the fraction is even more. It is worth to put into evidence that EF can be calculated both for the population of a community and for a single individual. To measure the level of sustainability of tourism it is worth to introduce another indicator able to express the role of GHG emission: the carbon footprint.

5.2. The carbon footprint

The carbon footprint (CF) is usually measured in kilograms of carbon dioxide equivalent; in the case of tourism the unit for this indicator could be kilograms of carbon dioxide equivalent/ person [20]. Tourism, as any other human activity, has either direct or indirect effects on the carbon footprint. The primary CF is the direct measure of carbon dioxide emissions from burning of fossil fuels (such as energy consumption at the destination and transportation). The secondary CF is a measure of the indirect carbon emissions from the entire life cycle of commonly used products (related to their manufacture and eventual disposal/breakdown).

In assessing the CF it should be kept in mind that electricity is an essential part of the tourism industry. Hotels and accommodation for guests must be fully equipped for their comfort; this includes proper lighting, water heaters, basic electronics, elevators, pool pumps, etc. Restaurants are generally run on electric stoves and in some cases, electric dishwashers (both currently considered negative for sustainability). For these reasons and many more, high amounts of electricity is needed hence a readily available, efficient supply is crucial. For electricity generation the CO₂ specific production for different fuels is shown in *Table 1*.

Fuel	f_c (Carbon Fraction in fuel)	Heat of Combustion [kcal/kg]	P [kgCO ₂ /kWh] (Thermal)	P _s [kgCO ₂ /kWh] (Electrical)
Natural gas	0.75	11900	0.20	0.5
Petrol	0.87	10000	0.27	0.67
Coal	0.85	8500	0.31	0.77

Table 1. Specific CO₂ emissions for different fuels.

It is, hence, evident that the specific emissions will depend on the relative amount of the different fuel used for the electricity production (energy mix). In *Table 2*, the specific production of CO₂ per kilowatt-hour for some European countries is reported.

The analysis of the carbon footprint of tourism worldwide shows that the greenhouse emissions are due to: transport (particularly air and motor vehicle) 82%, accommodation 4.5%; other activities 8.6% retail 3.4% [21]. The transportation of visitors to the destination plays an important role in contributing to the carbon footprint. However it should not be forgotten that transport is a promoter for the rest of the industry: if the number of trips declines significantly then all businesses will be affected.

Country	Emissions [kgCO ₂ /kWh]			
	Coal	Petrol	Natural Gas	TOTAL
Italy	0.118	0.130	0.178	0.426
Austria	0.097	0.019	0.076	0.192
Germany	0.382	0.011	0.046	0.439
Spain	0.223	0.057	0.081	0.361
France	0.036	0.007	0.015	0.057
Sweden	0.005	0.009	0.004	0.018

Table 2. Specific emissions of CO₂ for some EU countries.

6. Role of transportation in tourism

In modern societies mobility plays a fundamental and increasing role in shaping our daily life: the way people interact, work, play, manufacture, and get access to services, leisure amenities and goods, is inextricably linked with transport. Mobility lies at the heart of tourism and, noticeably, there are synergies between transportation and tourism [22], with technological developments and lower prices for the mobility promoting tourism and, conversely, tourism encouraging the expansion of new transportation possibilities. Furthermore, transportation is the link between home, destination, accommodation, attraction, and all other stages of a tourist journey. Its efficiency, comfort and safety determine to a large extent the quality of the tourist's experience and in many cases its cost comprises the largest portion of a tourist's total expenses. Tourism represents a strong sector for the demand of transportation and prospective studies foresee a further increase and, consequently, in the request for mobility to reach the termini and even at the destination itself. The trend to select far destinations has made the travel phase the prevalent part of the total economic and environmental cost.

On the other side, in evaluating emissions - as will be discussed in detail in the next paragraph - there is no doubt that tourism is an important contributor to the emission in general and of GHG in particular. Indeed, data from the WTO Climate Report shows that total CO₂ from tourist activities amounts to 4.9% of total world emissions, with mobility

playing a relevant role. A recent study made by the Direction des Études Économiques et de l'Évaluation Environnementale (D4E), revealed that mobility of French tourists gives a contribution to the GHG emissions of about 6% of the total amount (2006) [23]. Moreover, this study concluded, analysing the duration of the permanence in the destination in the last 40 years, that the average duration has changed from 20 to 12 days and that the portion of tourists spending vacation abroad changed from 12 to 19%, implying more frequent travelling and increased use of the airplane to reach abroad destinations.

Transportation is accomplished by different means, such as car, train, bus, ship, or aircraft. According to a study by [24], out of the total car transport, 20%-30% are used for tourism mobility. Similarly, 20%-40% of rail travel serves tourism purposes, whereas 60%-90% of air travelling passenger accounts for tourism mobility. At global level, tourism mobility causes around 75% of total CO₂ emissions out of all emissions from touristic activities, with aviation representing the bulk of it (40%). According to a research performed by [25] GHG emissions from international aviation grew by 87% between 1990 and 2004 (73% increase for 1990-2003), while total GHG emissions decreased by 5.5% between 1990 and 2003. Air traffic is furthermore expected to double in the next 15 years and is anticipated to counteract the reduction of CO₂ emissions achieved in other sectors.

Actually, the development of the air travel industry, especially low-cost airlines, has made affordable and thereby increased the utilization of this type of mobility, making travelling accessible to a growing number of the world's population. The air-travel industry has substantially reduced travel time and travel costs as compared to other transport modes. The most popular air-travel models are the Low Cost Carriers (LCCs) focusing on sea, sand and sun tourism, short stay city trips and cultural destinations [26]. To make flights to a destination cheaper, it is important flying non-stop. The contribution to emission given by the flights used for tourism is the highest (if expressed in terms of kg CO₂/person and km), even if it is not the most selected way to reach destinations for vacations: In France (2006) only 6% of tourists have selected the airplane to reach the destination, usually located very far away. Nevertheless, automobiles are still the most common way used for tourism travels (75%).

Energy consumption for transportation depends on two factors: the type of transport used and the distance to be covered. Due to the overwhelming use of fossil fuels, mobility generates GHG emissions which can cause climate change and engender impacts that harm the environment and is believed to be a primary cause of climate change. Hence, it can be concluded that transport represents an important phase of tourism but is, on the other hand, responsible of a outstanding amount of emissions. Nevertheless, when looking at tourism mobility we have to keep in mind that transport for tourism only accounts for a fraction of all transport. A large portion of general transport serves for moving freight and non-tourist passengers [27].

7. Emissions produced in tourism

Tourism activities, besides the necessary mobility to reach the destination briefly discussed in the previous paragraph, generate emissions also in other phases of its development such

as of residing at a destination as a result of the use of energy for heating or air conditioning, illumination, and other services (cooking, cleaning, office, etc.). All these aspects have to be considered to assess the energy consumption and related emissions during the tourism life cycle. In *Figure 4*, the different phases of tourism and its associated fuel and energy consumption are schematically depicted, substantiating that a touristic activity generates emissions in all the phases of its development. The figure evidences that energy consumption is partly due to travel (to the destination and back home) and partly to the activities performed in the destination. It has been determined that, if the distance from the departure location and the destination are relatively short (less than 1000 km) the preferred way for transport is the private car whereas, for long distances, air transportation is preferred. In the last years the relatively low costs of flights for long distance have encouraged journeys to destinations far away.

As already stated, energy consumption and its associated emissions in tourism depends on the type of services offered, the type of accommodation and the energy management approach. For instance, hot water supply, heating and air conditioning, account for a large part of hotels total energy consumption. As will be discussed later, appliances and utilities represent an area where large savings can be made through efficiency improvements. Accommodation providers should have a particularly strong interest in reducing energy consumption in order to save costs and ensure the sustainable future of the destination.

Although there are different ways to provide energy to tourism activities, large amounts of CO₂ are produced mainly due to the fact that energy is largely converted by burning fossil fuels. In *Figure 5*, the global GHG emissions per economic sector and particularly those due to the mobility, discussed in what follows, are shown.

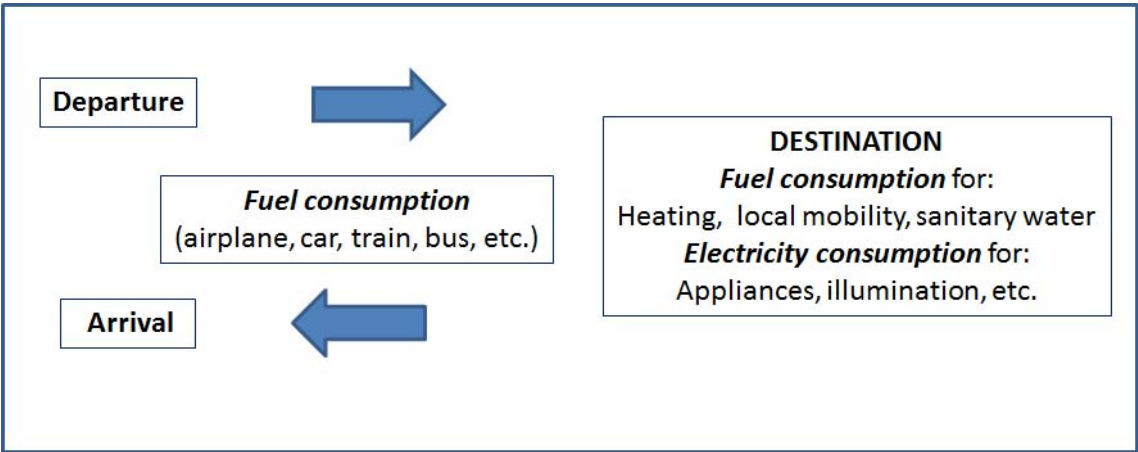


Figure 4. Schematic representation of fuel and energy consumption in the different tourism phases.

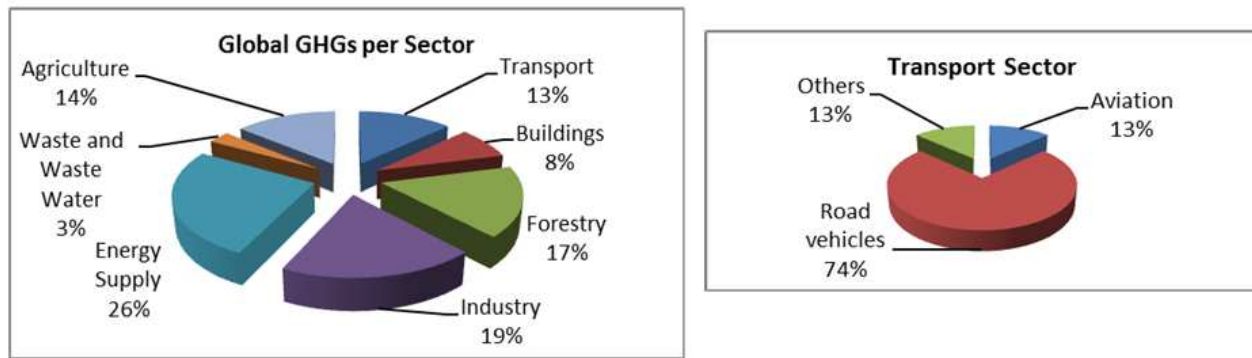


Figure 5. Global and sectorial emissions. Source: [28]

In *Table 3*, the amount of CO₂ emissions (in millions of metric tons) and the share of tourism in the different phases (in percentage of the total), is presented.

	CO ₂ - EMISSIONS	
	MT	SHARE OF TOURISM [%]
Air transport	515	40
Car	420	32
Other transport	45	3
Accommodation	274	21
Other activities	48	4
Total tourism	1302	100
Total world	26400	-
Share of tourism in total world (%)	4.9	

Table 3. Emissions of the different sectors, according to the WTO. Source: [29]

7.1. Emissions due to mobility

Transportation means emit large quantities of carbon dioxide (CO₂), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particulate matter (PM), and very dangerous substances such as benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and lead (where leaded gasoline is still in use). Each of these pollutants, along with secondary by-products (such as ozone), can cause adverse effects on health and the environment. Recognizing the danger the atmospheric pollutants can generate, many developed countries have issued strict emissions controls especially for particulate matter produced by road dust, tire wear, brake wear etc. In recent times much attention has been devoted to non-combustion substances and the so-called Particulate Matter (PM), both of which appear to be dangerous for the human health.

Transportation is a typical system belonging to the so called mobile sources: pollutants emitted are spread out along the pathway followed by the source. For part of the emissions

this might represent an advantage since they are diffused in the environment and pollutants undergo to a dilution process (e.g., particulate matter). This is not the case for GHG due to the fact that their effect belongs to the category of global impacts.

7.1.1. Emissions from air transport

Air traffic in the world is growing, and will likely continue to grow. A large part of the expansion of the number of flights is due to tourism, especially to far destinations (more than 1000 km). The majority (60 to 90%, depending on different studies) of air travelling passengers are ascribed to tourism mobility. The total contribution of aircraft emissions to total anthropogenic carbon dioxide (CO₂) emissions was considered to be about 2 percent in the IPCC 4th Assessment Report [28].

Although the contribution of aviation operations to total global CO₂ emissions is relatively small, forecasted traffic growth (4.7% per year) raises questions on the future contribution of aviation activity to emissions and, hence, to climate change, and on the most effective way to address CO₂ releases from the sector.

The effect of emissions from aircraft at high altitudes (especially nitrogen oxides (NO_x) and water vapor) is of particular concern. CO₂ and H₂O are the main combustion products but also products such methane, nitrous oxide and other gases have an important effect on the climate change. The fuel consumption and emissions will be dependent on the fuel type, aircraft type, engine type, engine load and flying altitude.

Emissions from aircraft originate from fuel burned in aircraft engines with two types of fuels used. Gasoline is used in small piston aircraft engine only. Most aircraft run on kerosene, and the bulk of fuel used for aviation is this type of fuel. In an effort to improve efficiency, part of the energy contained in the hot discharged gas is used to drive the turbine that in turn drives the compressor.

GHG emissions of the airplane strongly depend on the type of aircraft and on the distance covered. In analyzing the emissions due to air transport, it is usual to distinguish between the different phases of a flight. The cycle is named Landing/Take-Off (LTO); it includes phases located below 1000 meter (taxi/idle, take -off and landing). The phases of a flight cycle are shown schematically in *Figure 6*.

In short travels the contribution of LTO to fuel consumption and of CO₂ emissions is very high. This is the reason why flights covering long distance become more convenient in terms of amount of CO₂ emitted per km. In fact, an analysis conducted for many types of aircraft show the indicative data for LTO cycle gathered in *Table 4*.

In order to understand better the effect of LTO on the fuel total consumption in covering the distance and the related CO₂ emissions, a modern airplane, traveling a distance of 2000 km with a number of passengers of 200 people is taken as reference. For such a plane, a specific emission of 5 kg/km passenger and a LTO emission of 2000 kg can be assumed. If the travel is performed non-stop 2000 km total emissions will be 10000 (cruise flight) + 2000 for LTO, this means that LTO weight 20%. Obviously, if the number of km is increased to 4000, the

percentage of LTO will become only 10%. It appears clear that for short distances the choice of airplane is not favored in comparison with train, bus and car both from economical neither ecological point of view. Obviously, for a long haul a non-stop trip is strongly recommended.

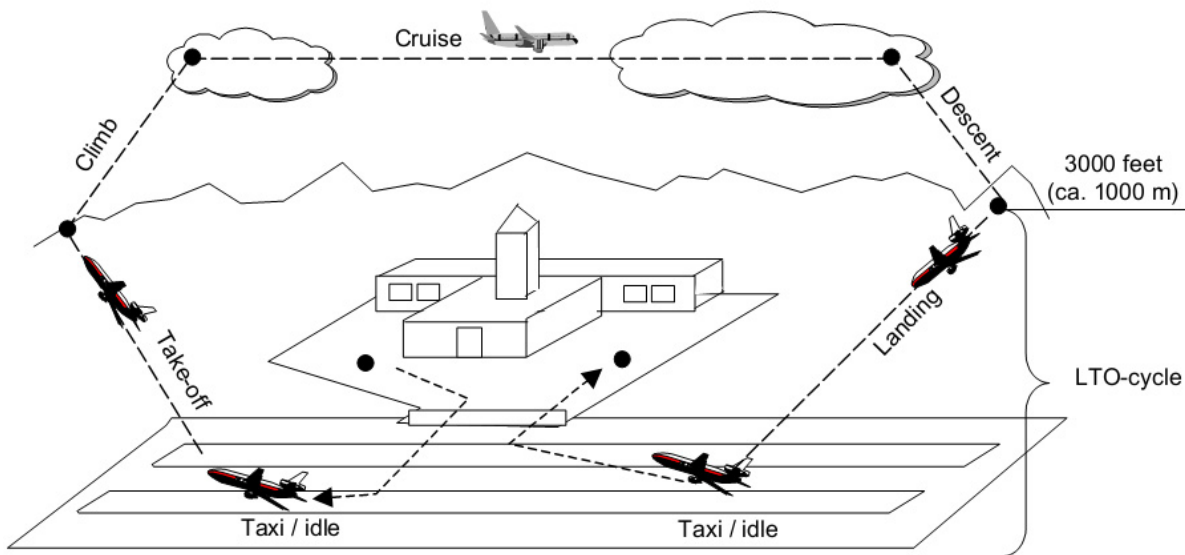


Figure 6. Standard flying cycle. Source: [30]

POLLUTANT	(kg/LTO)
CO ₂	3000 – 10000
CH ₄	0.1 - 4
N ₂ O	0.1 – 0.3
NO _x	5 - 15
CO	10 - 50
NMVOC	10 - 50
SO ₂	1 - 3
Fuel	1000 – 3000

Source: [30]

Table 4. Indicative pollutants and related fuel consumption ranges for different aircraft

Concerning the fuel consumption, passenger airplanes in the year 1998 averaged 4.8 l/100 km per passenger (1.4 MJ/passenger-km). In this context it has to be mentioned that, on average, 20% of seats are left unoccupied. Jet aircraft efficiencies are improving: between 1960 and 2000 there was a 55% overall fuel efficiency gain. Companies using Airbus state a fuel rate consumption of their A380 at less than 3 l/100 km per passenger.

7.1.2. Car transportation

In particular, in developed countries people rely heavily and increasingly on private mobility and the vehicles are expected to become safer but, disappointingly, also more luxurious and

powerful. In addition, automobiles and other means of transportation are driven and used progressively more frequently. This individual and collective attitude often does not take into account the resulting consequences: increased traffic congestion land occupation for parking lots in urban areas, increased fuel consumption, greater emissions of air pollutants and greater exposure of people to hazardous contaminations that might cause serious health problems.

As awareness concerning the potential health effects of air pollutants has grown, many countries have implemented more stringent emissions controls and made steady progress in reducing the emissions from cars, buses, airplanes in a perspective of improving air quality and limiting GHG emissions. However, the rapid growth of the world's transportation fleet due to population and economic growth, the expansion of metropolitan areas, and the increasing dependence on motor vehicles because of changes in land use, has resulted in an increase in the fraction of the population living and working in close proximity to busy highways and roads, counteracting to some extent the expected benefits of pollution control regulations and technologies. Pollution produced by cars, buses and ships in tourism activities are giving a great contribution to total GHG emissions. According to a study by [24] out of total car transport, 20%-30% are used for tourism mobility.

Pollutants from vehicle releases are related to vehicle type (e.g., light- or heavy-duty vehicles) and age, operating and maintenance conditions, exhaust treatment, type and quality of fuel, wear of parts (e.g., tires and brakes), and engine lubricants used. Concerns about the health effects of motor-vehicle combustion emissions have led to the introduction of regulations and innovative pollution control approaches throughout the world that have resulted in a considerable reduction of exhaust emissions, particularly in developed countries. These reductions have been achieved through a comprehensive strategy that typically involves emissions standards, leading to the introduction of cleaner fuels and accurate vehicle inspection programs.

The European Union has introduced stricter limits on pollutant emissions from light road vehicles, particularly for emissions of nitrogen oxides and particulates. In order to limit pollution caused by road vehicles, specific regulations have been introduced for emissions from motor vehicles. The European Regulation No 715/2007 deals with vehicles with a mass not exceeding 2610 kg. It includes both positive-ignition engines (petrol, natural gas) and compressed ignition (diesel engines). In order to limit as much as possible the negative impact of road vehicles on the environment and health, the regulation covers a wide range of pollutant emissions: carbon monoxide (CO), non-methane hydrocarbons and total hydrocarbons, nitrogen oxides (NO_x) and particulates (PM). It covers tailpipe emissions, evaporative emissions and crankcase emissions. For each category of pollutant and for the different types of vehicle limits are given. In *Table 5* the limits (**Euro 5 Standard**) fixed for light road vehicles are shown. The regulation in force for European cars requires the respect of the limits.

An important figure for all transportation means is the CO₂ emission directly connected to the chemical composition (carbon %) of the fuel and to the efficiency of the engine. If a car needs 5 liter of gasoline to travel 100 km this means that emissions are $5 \times 0.86 \times (44/12) = 15.8$ kg CO₂ per

100 km, or 158 g CO₂/km. Usually CO₂ specific emissions are expressed in g/km, so our car would have emissions not particularly good i.e. 158 g CO₂/km. Designer of modern cars are giving utmost attention to this performance of cars, advertising of new models with specific emissions of less than 100 g CO₂/km. If this target will be reached for a large portion of car park, the global problem of climate change would be strongly reduced. Emission less than 100 g/km are considered acceptable for the environment and above 200 g/km have to be considered too high. Obviously, the lower the CO₂ output, the lower environmental impact. In the following some characteristic of small cars with low specific emissions are shown. In Table 6, the advertised CO₂-emissions for some commercial small cars are gathered.

	POLLUTANT	EURO 5 EMISSION LIMIT (mg/km)
EMISSIONS FROM DIESEL VEHICLES	Carbon Monoxide (CO)	500
	Particulate Matter (PM)	5 (80% reduction of emissions in comparison to the Euro 4 standard)
	Oxides of Nitrogen (NO _x)	180 (20% reduction of emissions in comparison to the Euro 4 standard)
	Combined emissions of Hydrocarbons and nitrogen oxides (HC+NO _x)	230
EMISSIONS FROM PETROL VEHICLES OR THOSE RUNNING ON NATURAL GAS OR LPG	Carbon Monoxide (CO)	1000
	Non-Methane Hydrocarbons (NMHC)	68
	Total Hydrocarbons (THC)	100
	Oxides of Nitrogen (NO _x)	60 (25% reduction of emissions in comparison to the Euro 4 standard)
	Particulates (solely for lean burn direct- injection petrol vehicles)	5

Table 5. Limits for diesel and petrol vehicles. Source: [31]

MODEL CAR (STANDARD)	emissions (CO ₂) range (g/km)
Italian small car	109-113
French small car	87-153
Japanese small car	95-125

Table 6. Specific emissions of modern small cars according to the advertising

7.1.3. Other transportation means

Among the carriers used for tourism also cruise ships, able to transport several thousands of people, have to be included.

Apart from aviation, the worldwide booming cruise ship industry has also come under increased criticisms. Cruise ships that can carry up to 5000 tourists are not only notorious for creating tremendous amounts of waste and sewage but also belong to the biggest contributors to greenhouse gas emissions within the travel and tourism industry. A single cruise ship can generate emissions equivalent to more than 12400 cars. The ship smokestacks release toxic emissions that lead to acid rain, global climate change, and damaging health effects to communities situated near ports. Despite the fact that ocean cruise liners are more energy efficient than other forms of commercial transportation, marine engines operate on extremely dirty fuels, known as 'bunker oil'. To compound the problem, engines on these ocean-going ships are currently not required to meet the same strict air pollution controls, as cars and trucks are required to do.

Referring to the fuel consumption per single passenger and unit of distance covered (*Table 7*), it is found out that the specific consumption and the related CO₂ emissions are greater than the emissions of an airplane. Rough estimates indicate for cruise liner emissions of about 0.27 kg of CO₂ per passenger and kilometer, as compared to 0.16 kg for a long-haul flight. The cruise industry is the fastest growing sector of the travel industry. In 2003, 9.3 million passengers took a cruise. These figures indicate that if not enough attention is paid to carbon emissions, due to the increased popularity of this type of vacation, the contribution will become not negligible without appropriate improvements in the design of cruise liners.

Concerning railway transportation, it has been estimated that 20%-40% of rail travels serve tourism purposes. Taking into account that most of the rail traces are electrified, rail transportation seems good for the environment. Nevertheless, taking into account the whole cycle, the source of electricity has to be considered, then, if fossil fuels are used, the emissions at the basis has to be included.

The impact of air transportation on climate is exacerbated by the fact that the emissions happen largely during cruise phase and, hence, mainly in the higher layers of atmosphere. Here the impact is due not only to CO₂ but also to other emissions, such as water vapour and nitrogen oxides. The increase of the effect on climate is usually given through a coefficient called radiative forcing, defined as the change in the net irradiance in the

different layers of the atmosphere. The Intergovernmental Panel of Climate Change estimates that the warming effect of aircraft emissions is about 1.9 times that of carbon dioxide alone, due to the other gases produced by planes.

The contribution of tourism to global climate change through GHG emissions from the transportation of millions of tourists was first discussed in the middle of 90's. Subsequently, a direct interest by the IPCC has started, devoting attention to tourism in the some regional such as Africa, Australia and New Zealand, Europe and small island states. Later on, a tourism-focused climate change assessment was commissioned by some international organizations to evaluate the relative regional vulnerability of tourism destinations, discussing the state of adaptation within the sector and providing the first quantitative estimate of the contribution of the global tourism sector to climate change, aiming to set out options for decoupling future growth in the tourism sector from GHG emissions. Although recent events such as seismic incidents, hurricanes and tornadoes, the Asian tsunami, and even terrorism attacks, suggest a relatively high adaptive capacity of the sector, whether the touristic sector will be able to cope successfully with future climate regimes and the broader environmental impacts, remains relatively unknown.

MEANS OF TRANSPORT	KILOMETRES PER LITRE [kpl]	EMISSIONS [g CO ₂ /km passenger]
Car - the most efficient	18-23	130-100
Car - average models	9-16	260-145
Car large models, SUVs, etc.	3-9	500-250
Rail - normal suburban	18-52	130-145
Rail - high speed, few stops	14-28	165-180
Bus - well used service	28-50	80-145
Airplane - (below 500 miles)	4-8*	460-330
Airplane - (long journeys)	8-12*	330- 210

* including radiative forcing index at 1.9

Table 7. Summarizes the present situation concerning mobility. Source: [32]

7.2. Accommodation

The emissions due to the consumption of energy in the destination can be expressed in terms of heat and electricity consumption in the period of staying (number of days). The electricity consumption in the destination can be safely assumed equivalent to the typical consumption of a user at home, which amounts 3 kWh per person and per day. This figure changes with the type of hotel or resort and depends also from the existing degree of energy saving of the accommodation. Heating consumption can also be estimated taking into account meteorological conditions and the thermal isolation provisions isolation of the building. Sound figures for modern building range between 70 to 100 kWh per m² per year. Data in kg of CO₂ can be obtained by conversion factors.

Pollutants produced in tourism destinations have a limited importance if we consider only the impact produced in the accommodation structures. Pollution produced by electricity is not a local problem since its effect takes place directly on the site where the power stations are located; the small amounts of pollutants produced locally can be controlled by adequate systems based on high efficiency and right behavior. Moreover, a complete analysis of local air pollution should take into account the contribution given by cars of tourists circulating in the destination determining an overburden of air pollution, noise and traffic jams.

8. Sensitivity of tourism to climate change

From what we have discussed in the previous paragraphs, the synergy between tourism and environment results evident, particularly due to the interrelation between energy consumption for tourism in all its phases and the emissions produced in the process of energy conversion, believed to be the cause for climate change. In fact, the previous paragraphs demonstrated that tourism activities produce a significant amount of greenhouse gases, contributing thereby to global warming which, in turns, may affect the local climate. Moreover, it is now widely recognized that, among the different causes of greenhouse gases emissions due to tourism activities, travels to long distance destinations (which are increasingly requested in the current tourism market) generate most greenhouse gas emissions and are, thus, supposed to contribute strongly to climate change.

Many research studies consider climate as an essential resource for tourism, and especially for beach, nature and winter sport tourism, and the phenomenon of global warming already severely affects the sector in an increasing number of destinations. It is thereby recognized that the impacts of global warming pose a serious threat to tourism, which constitutes one of the world's largest and fastest growing economic sector [1], according to the World Travel and Tourism Council (WTTC) [33]. As already stated, the relationship between climate change and tourism is two-fold. Not only is tourism affected by a changing climate, at the same time it contributes to climate change by the consumption of fossil fuels and the resulting emissions. Hence, additional efforts are underway to develop environmental policies for the tourism sector that can offer adaptation and, where possible, mitigation.

The predicted modifications caused by the climate change in the tourism destinations due to global warming, are anticipated to be predominantly strong for coastal areas, whose environmental conditions appear particularly sensitive. It has been estimated that about 25% of the CO₂ emitted from all anthropogenic sources currently enters the ocean, where it reacts with water to produce carbonic acid. Carbonic acid dissociates to form bicarbonate ions and protons (see *Figure 7A*).

The protons react with carbonate ions to produce more bicarbonate ions, reducing thereby the availability of carbonate to biological systems (e.g., corals). This decalcification phenomenon might affect both skeletal growth and density, with consequences on the extension of the coral reefs and their mechanical endurance (less resistance to storms and erosion). This phenomenon is evident in many coastal zones, particularly in the Australian coralline barrier, manifesting itself through the so-called coral bleaching (*Figure 7B*).

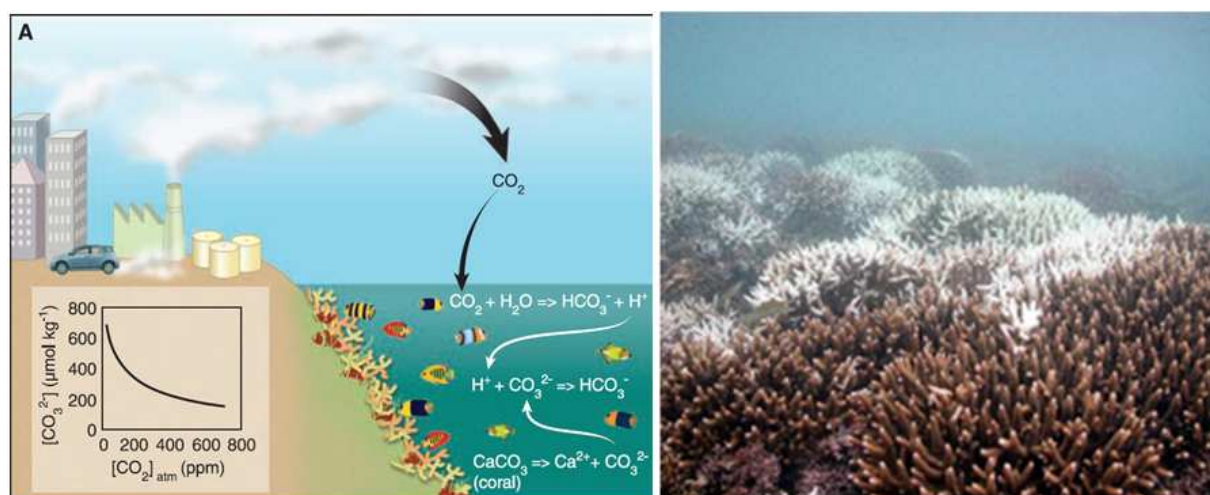


Figure 7. Ocean acidification process (A) and the resulting coral bleaching (B). Source: [34, 35]

Since sea-coast tourism remains one of the dominating market segments, giving a high contribution to the economy of many developing countries, the vulnerability of coastal destinations becomes of paramount importance [1]. In addition to the particular example discussed, it is expected that local effects of global warming, such as the increase of local extreme events (storms, coastal erosion, sea level rise, flooding, water shortages and water contamination), can put in danger beach destinations. As already mentioned, the enhanced vulnerability is often accompanied by a low adaptive capacity, which is particularly true for coastal destinations of developing countries. The seasonality of coastal tourism is an additional facet to be taken into account in the panoply of problems created by the climate change. Generally, coastal areas tourism is concentrated in few months, coinciding e.g., with low water availability, high consumption of fuels, electricity, etc. In some expected conditions global warming could also play a positive role; this could be the case for Mediterranean destinations where the season could be enlarged and the winter period might be more appealing to tourists, providing opportunities to reduce seasonality and expand the tourism product. In addition to the absolute amount of change, the rate at which change occurs is critical to whether organisms and the ecosystem in general will be able to adapt or accommodate to the new conditions.

On the basis of the few examples discussed, it is evident that the interaction between tourism and climate is very complex and has only recently been established as the subject of scientific studies and recognized as the cause of growing contribution to climate change and, hence, the main reason for regional vulnerabilities. In this sense, a recently declaration of UNWTO-UNEP-WMO stated that *"climate change must be considered the greatest challenge to the sustainability of tourism in the twenty-first century"* [29]. Although the interaction between tourism and climate change has been studied to some extent in the last 20 years, there are only few recommendations in specific issues and a real strategy of approach is not yet available.

9. Making tourism more sustainable

Tourists' increasing concerns for environmental issues have also stimulated operators in the sector to adopt sustainability strategies. It is now widely recognized that tourism is in many cases not sustainable, even if some sorts of sustainable tourism and ecotourism are making efforts to enhance and promote local development while simultaneously protecting the natural environment, maintaining traditional and cultural heritage. In fact, many tour operators cooperate with local tourism authorities and environmental agencies to promote ecotourism and other forms of sustainable tourism. Making tourism more sustainable is not just about controlling and managing the negative impacts of the industry; tourism is in a very special position to benefit local communities, economically and socially, and to raise awareness and support for conservation of the environment and cultural heritage, even providing in some cases the basis for scientific research.

Tourism was once viewed as an independent activity, having no impact on environmental resources but in reality, this seldom occurs. Therefore, it is urgent that civic movements concerned with environmental and climate change issues, monitor and respond to these type of activities, since T & T is, for many countries one of the most important industries, not only because of its size and foreseeable growth but also due to the fact that it is considered a driver of globalization and trade liberalization. Nevertheless, in this context, the argument of tourism as a poverty alleviation strategy is doubtful in view of the increasing foreign take-overs of tourism businesses as a result of globalization and liberalization.

In general, the main requirements for improving sustainability in tourism are: to limit resource depletion and degradation including loss of biological diversity, loss of habitat and resources, loss of water resources; fisheries; forests and timber; energy resources; mineral resources. Moreover, improvement of sustainability could be pursued by reducing pollution and wastes production. The process of enhancing sustainability also includes actions addressed at improving the quality of life of host communities, at preserving intergenerational and intra-generational equity and ensuring the cultural integrity and social cohesion of communities, giving at the same time the opportunity to provide a high quality experience for visitors. Other interventions to improve sustainability deal with the promotion of the economic growth connected to tourism activities (hotels, restaurants, beach facilities, entertainment initiatives, etc.).

The measures proposed to reduce environmental impacts at destinations include: avoiding exhaustion and degradation of water resources; deterioration/loss of habitats (i.e. sand dunes), deterioration of terrestrial ecosystems; abandonment of agricultural land, urbanization with loss of urban landscape character, landscape deterioration, soil erosion, desertification, depletion/ significant decrease of fish stock, loss of historic settlements, depletion of low-commercial-value sectors, replacement of pre-existing architecture, concentration of vehicles in the urbanized areas, high level of noise pollution during the day and at night, degradation and fragmentation of natural spaces, loss of open spaces, oversized public services and infrastructures; increased production of waste; deterioration

of the shoreline marine environment, bad relations between local population and tourists, depletion of pre-existing economic activities, high human density in the areas generally used by the tourists.

It is evident from what reported in the previous paragraphs that, evaluating the sustainability of tourisms, a major problem is represented by the quantification of tourism GHG emissions. One of the recommendations, suggested in some analysis of the sector, is the possibility to apply the indicator “carbon footprint” (discussed in paragraph 4) to tourism activities to make more comprehensible the role of tourism on GHG emissions. This parameter could be useful to improve the behavior of tourists and tourism operators, guiding them toward “greener forms” of tourism and mobility, such as “slow tourism travel” and different types of ecotourism. Among the different solution to reduce GHG emissions there are some oriented toward a specific goal, the so called carbon neutrality for tourism, proposed by the administration of some famous tourism destinations: *carbon neutral tourism implies the offsetting of a destination's carbon footprint by means of processes balancing carbon emissions, such as planting trees or investing in new, renewable, energy sources.*

10. How to reduce emissions and the environmental impact of tourism

Aiming to reduce air pollution and GHG emission, the tourism industry is usually divided into different sectors: accommodation, catering services, recreation and entertainment, transportation and travel services, etc. In all these sectors actions to reduce the carbon footprint are possible. However, it is widely recognized that two these phases are the main responsible for emissions of pollutants: energy consumption and related emissions at the destination and fuel consumption and related emissions during traveling [36].

10.1. Reduced emissions and environmental impacts at the destination

To diminish emissions at the destination, reduction can be achieved by simple interventions that can be very valuable also from an economic point of view, reducing costs. To this goal, better use of electricity, water and handling of waste can greatly contribute in terms of sustainability and economy, as well as reducing emissions. Some examples for electricity saving are to turn off power of lights and equipment when not in use; install energy efficient fluorescent bulbs; use natural ventilation and fans where possible and when using air conditioning, set it to between 24°C and 28°C in summer. Appreciable amount of heat flow can be reduced by controlling the temperature in the inner spaces, and by an efficient thermal insulation of the wall, doors and windows. An important contribution to the reduction of air pollution and GHG emission can be obtained by limiting the private transport in the destination both for tourist's mobility and freight. An additional important measure is to eat food produced in the destination itself, what it is called “zero km”. Other recommendations are concerned with the use of public transport and car-pooling, use of low consumption cars such as hybrid or electric vehicle, encourage cycling and walking where possible, use phone/video conferencing to reduce travel requirements. A further measure to reduce emissions is to change the fuel used for energy conversion from fossil fuels to the

adoption of renewable sources such as biomass, eolic and photovoltaic systems. When staying in a hotel turn the lights and air-conditioning off when leaving the room, ask for room towels not to be washed every day which increasingly proposed in many hotels. Main factors taken into account for low consumption energy are the supply devices used for electric lamps, motor-driven appliances and electronic devices as well as heating systems.

To these goals, a new kind of eco-tourism is developing with specific requirements in terms of reduced energy consumption dictated by an extremely high contact with nature in remote destinations. Accommodation is made by the so-called eco-lodges, typical structures designed to have the least possible impact on the natural environment in which it is situated. Since there is no connection with the electricity grid, the eco-lodges are equipped with renewable and non-renewable energy sources and technologies for off-grid facilities. Energy consumed in eco-lodges is very low if compared with the specific consumption of hotels (25 kWh per guest and night in hotel vs. 0.5 kWh per guest and night in eco-lodge).

10.2. Reduce emissions due to mobility

The most advanced program to reduce GHG emissions in tourism have been done in the aviation sector. The *International Air Transport Association* (IATA) has advanced a range of very ambitious goals [37], including an average annual aviation fuel efficiency improvement of 1.5%, carbon-neutral growth from 2020 and the reduction of emissions from aviation by 50% by 2050 (compared with 2005 levels).

A reduction of flights would limit the profitability and growth of the tourism sector. However less drastic measures are possible, such as avoiding stops between the starting point and the destination. The question thus arises if it is possible to reduce the fuel consumption of airplanes with technological innovations. The gains reached and expected by technological innovation are represented in *Figure 8* [41] showing a reduction in fuel consumption of about 70% in the period 1960 – 2010. Further improvements are expected in the coming years but with a decreasing steepness of the slope of the curve.

Comparing the fuel consumption of a modern airplane (Airbus A380) with that of an efficient car offers interesting conclusions about the technological improvements in airplane design. The Airbus A380 is a four-engine airliner manufactured by the European corporation Airbus and the largest passenger airliner in the world. It provides seating for 525 people in a typical three-class configuration or up to 853 people in all-economy class configurations. Airbus A380, known under the nickname Superjumbo, is the first aircraft to surpass the 3 liter per 100 seat-km barrier. Taking into account a typical occupancy rate of 70% this translates into 4 liter per 100 km per passenger, about the same as a small car with an average load of 1.25 passengers.

A recent study made in France has analyzed the different ways to reduce fuel consumption [39] arriving to the conclusion that a reduction of 50% can be achieved in the year 2020. Measures that should be adopted to reach this goal are:

- Use of composite materials and ameliorate the aerodynamic design (5 to 15% efficiency improvement)

- Better motors or turbines, such open rotor turbines (15 to 25% efficiency improvement)
- Green taxi of planes (using electrical motors), optimize the traffic management and navigation system (10 to 25% efficiency improvement)

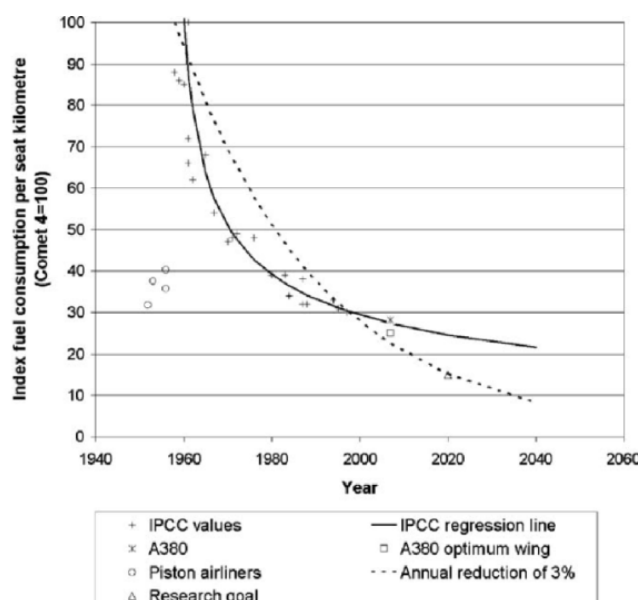


Figure 8. Long haul aircraft fuel efficiency gains since 1950 as an index (100) of De Havilland DH106 Comet 4. Source: based on Peeters et al. (2005) [38]

In Europe the air transportation cost is due for one third to the kerosene, but if the price of oil continues to increase at the present pace, the contribution of fuel could become 50%. A typical aircraft A320 consumes about 15000 litres for a travel of 2000 km. As already mentioned, a considerable saving of energy for the airplane sectors could be obtained by the use of systems operated with electricity instead of using the engines of the aircraft for displacing the airplanes on the taxiway. Further saving can be expected from the reduction of the weight of the aircraft by employing lighter materials and aerodynamic shapes.

Other possibilities to reduce energy consumption from tourism mobility are related to a marginal portion of the tourism market: these include the idea of “slow tourism” or other forms of responsible tourism. In some cases, the use of bus or a train rather than private cars or domestic flights can be advantageous. To fuel cars, airplanes and buses liquid biofuels such as bioethanol and biodiesel can be used.

In tourism activities a further contribution can be obtained with the so called carbon offsets, a process able to reduce a corresponding amount of carbon in the atmosphere by planting trees. If the destination is not far away the contribution to the total emissions can be limited, the production of CO₂ being done in the destination. If the distance is far away, the major part of the emissions are due to transportation, particularly if the travel is by flying.

A comparison of the emissions from different transportation means can be performed by introducing the relationship existing between the specific consumption (X) in km per liter of fuel and passenger and the specific amount of CO₂ in kg per km and passenger (Y); the

calculation of the CO₂ emissions from different means of transportation can be performed as follows:

$$X * Y = k$$

Where k is constant that can be expressed for 1000 grams of fuel as:

$$k = 1000 * C * D * MW / AW$$

Where C is the fraction of carbon in the fuel, D the density of the fuel, MW is the molecular weight of CO₂ and AW the atomic weight of carbon, respectively.

Representative values for three different fuels: gasoline (cars), kerosene (airplanes) and diesel (cars) are gathered in *Table 8*, and presented together with the calculated specific constant k and the typical range and average CO₂-emissions.

FUEL	DENSITY [kg/dm ³]	RATIO C/CH	SPECIFIC CONSUMPTION		k [g CO ₂ /liter fuel]	CO ₂ - EMISSIONS [g CO ₂ /km·passenger]	
			[km/liter]	[km/liter· PASSENGER]		TYPICAL RANGE	AVERAGE
gasoline (cars)	0.752	0.86	15 - 25	12 - 20	2371	110 - 183	146
kerosene (airplanes)	0.795	0.86	-	4 - 12	2507	210 - 460	335
diesel fuel (cars)	0.850	0.86	15 - 25	12 - 20	2680	86 - 95	90

Table 8. Typical values of CO₂ emissions for the three different fuels.

The relationship just introduced can be graphically represented in a series of parametric curves (see *Figure 9*), where the points represent the average values for cars and airplanes and are solely indicative of typical conditions. More accurate figures have to be referred to specific conditions, which will depend on the number on passengers, the length of the travel, the stops in between (for air transportation), the percentage of the seats occupied, etc. For instance, if for cars traveling long distance an average of 1.25 passengers per automobile is assumed, for distances below 1000 km, the best choice seems to be diesel car (due to the more efficient diesel engine) followed by gasoline car and finally by air transportation.

Furthermore, the curves indicated in the graphic can be used to assess the energy requirement for different vacation scenario, assuming a hypothetical destination 1000 km away from the starting point and a resident time for a single tourist of 7 days. According to the data gathered in *Table 9* and *Figure 10*, the way to make a vacation more sustainable from the point of view of emissions is to combine a limited CO₂ emission in the phase of staying at the destination and to travel with a high efficient transportation means such a diesel car. The use of airplane is usually the worst choice from an environmental point of view, since it produces more than three times the emissions of a medium size car.

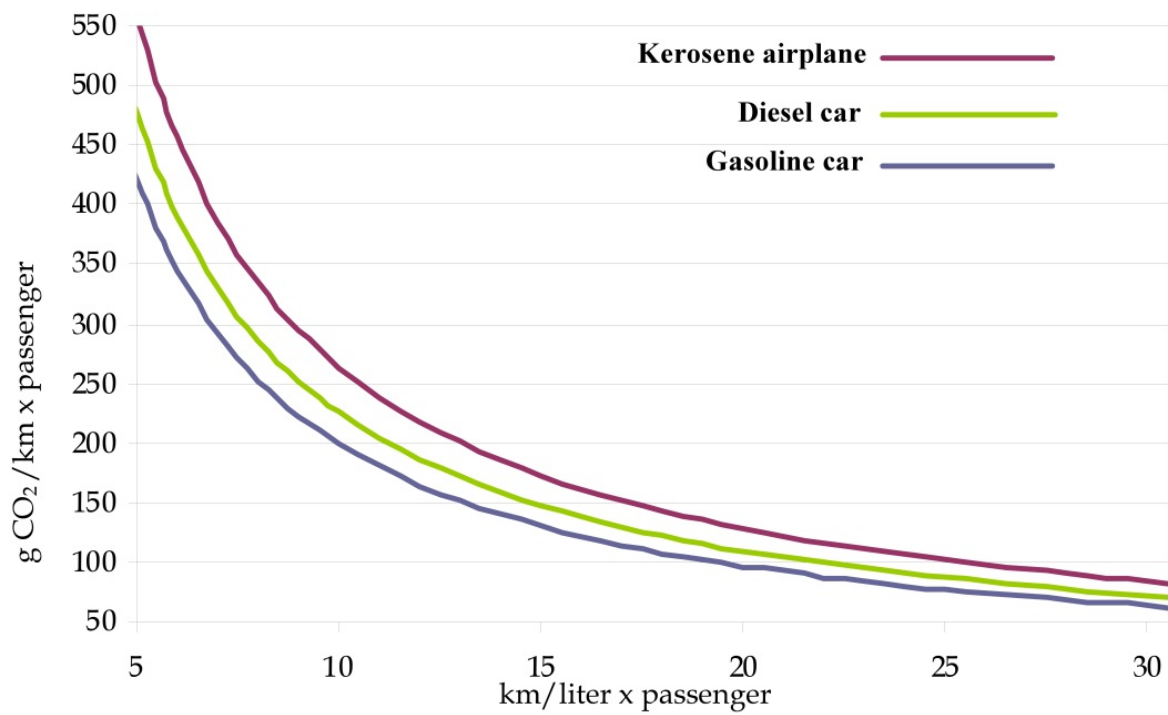
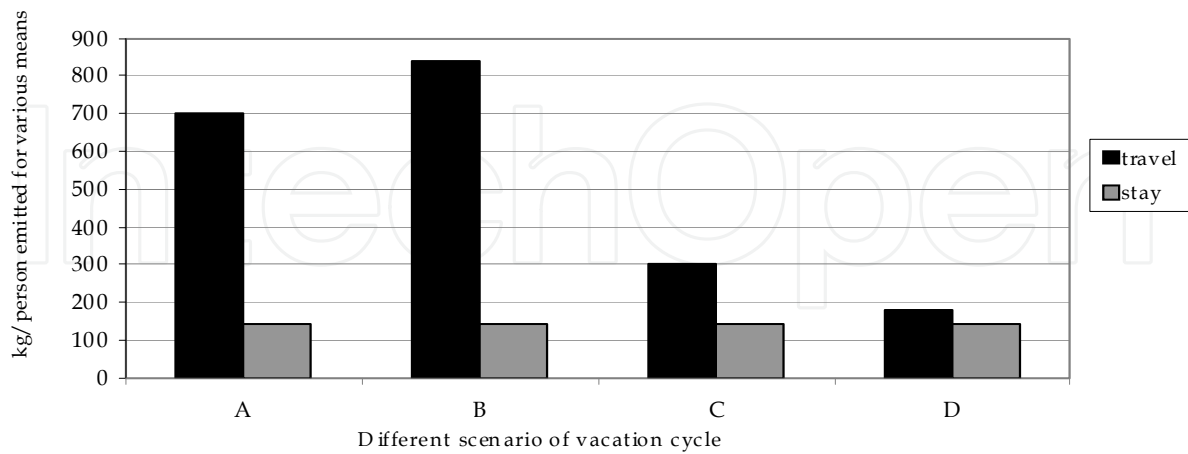


Figure 9. Specific CO₂ emissions for different type of fuel and transportation means.



** Energy consumed at hotels. Source: [40]

Table 9. Specific CO₂ emissions different vacation scenarios.

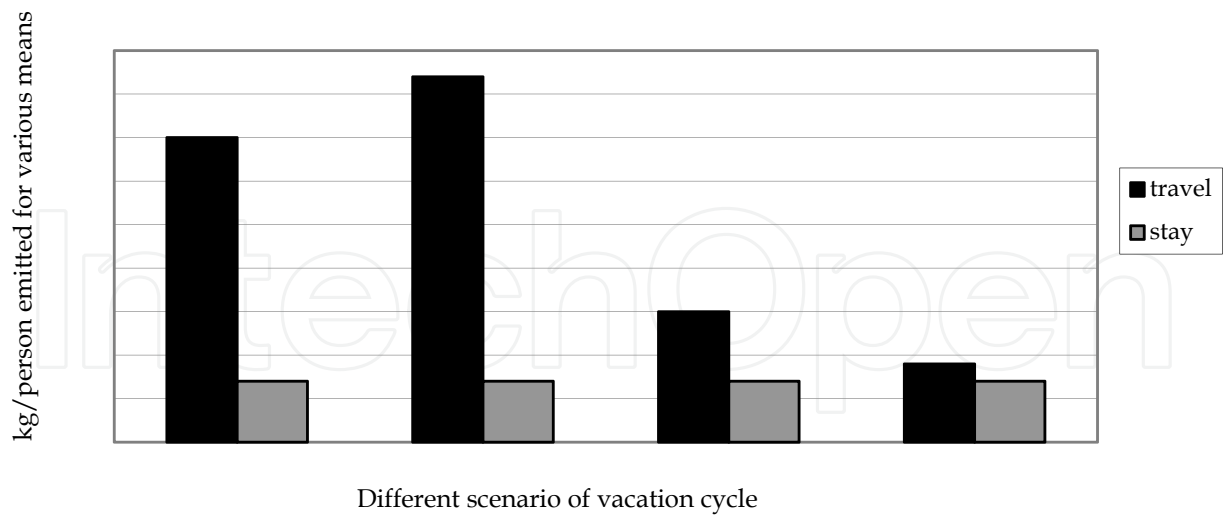


Figure 10. CO₂ emissions from vacation cycle (according to *Table 9*).

It appears that the best way to make sustainable T & T, from the point of view of climate change is to combine a limited CO₂ emission in the phase of staying and to travel with a high efficient transportation means such a diesel car. The use of airplane is usually the worst from an environmental point of view, even if it is more comfortable having a lower duration of the travel, but it produces more than 3 times the production of a medium size car.

11. Conclusions

T & T is a vector of climate change due to the GHG-emissions during the different phases of its development. On the other hand, the resulting climate change can compromise the environmental quality of a tourist destination, since climate conditions co-determines the suitability of locations for a wide range of tourist activities (sun, sea, snow, etc.). Hence, reduction of emissions constitute an essential component of T & T sustainability, particularly in the phase of mobility.

The analysis presented in this chapter shows that the reduction of greenhouse gas emissions from tourism mobility is economically unsustainable. The conclusion that air travel is the main cause of carbon footprint of tourism could bring to a reduction of this kind of transportation but a reduction of flights, would probably limit the profitability and growth of the tourism sector. Such a position would negatively affect the air transportation sector and would also produce a significant negative impact on tourism. However less drastic measures are possible, such as avoiding stops between the starting point and the destination. In addition, in order to reduce the threat of emissions, the aviation sector has already responded with a range of measures able to reduce fuel consumption such as fleet upgrades and changes in environmental practices. The question, thus, arises if it is possible to reduce the fuel consumption of airplanes with technological innovations.

At the destination, the application of different policies and measures to increase the sustainability of the T&T supplies to the consumers solutions that can be easily implemented, with the additional advantage of economic rewards. From a more general point of view, helping local communities to adopt practical strategies to deal with impacts of a changing climate, approach to a holistic, sustainable management through programmes for local development, e.g., protecting children, combating epidemics and promoting healthy eating, and adopting measures that include reduction of water and energy consumption, improvement of waste sorting, recycling and disposal, measures to preserve biodiversity, etc., can significantly improve T & T sustainability.

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