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## **MEASURING CARBON FOOTPRINT FROM TOURISM ACTIVITIES IN CRETE, GREECE: AN IN-DEPTH EXAMINATION**

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**Abstract:** Climate change, a pressing global environmental issue, poses multifaceted challenges to society. The 2015 Paris Climate summit yielded international consensus on policies and strategies essential for combatting anthropogenic climate change. Concurrently, the tourism industry, experiencing remarkable growth with a surge in annual travelers, must address its carbon footprint to actively contribute to global climate change mitigation efforts. Crete, a prominent Mediterranean destination, attracts a growing number of visitors annually, predominantly via long-distance international flights. Quantifying carbon emissions attributed to tourism on the island is instrumental in devising strategies for their reduction and offsetting. Emerging research underscores the sector-specific disparities in carbon emissions within the tourism industry, necessitating distinct approaches for emissions reduction in each domain.

**Keywords:** Climate Change, Tourism Industry, Carbon Emissions, Climate Change Mitigation, Crete Island.

### **1. Introduction**

Climate change consists of a severe global environmental problem having many undesired consequences in all aspects of daily life. During the Paris Climate summit in 2015 the international community agreed on various policies and measures necessary for mitigation of anthropogenic climate change. Tourism is a flourishing industry worldwide with an increasing number of visitors travelling every year. Like other industries, it is necessary for tourism to decrease its carbon footprint in order to contribute in the global effort of climate change mitigation. The island of Crete is a popular tourist destination in the Mediterranean basin with an increasing number of visitors every year arriving mainly with long-distance international flights. Estimation of carbon emissions due to tourism in the island will assist in finding ways for their reduction and their offsetting. Current studies indicate that carbon emissions in various sectors of the tourism industry are unequal and the approaches of their reduction in each sector would be different.

### **2. Literature Survey**

#### **2.1 Carbon emissions and tourism**

A study on tourism and climate change has been reported by the **United Nations World Tourism Organization (UNWTO), 2017**. According to this report transport accounts for 75% of all carbon emissions by the tourism sector, with aviation making up about 40% of all tourism emissions, road transport 32% and other forms of transport 3%. Accommodation represents about 21% of the total tourism sector emissions. The report also mentioned that international tourism contributes 4.95% to world total carbon emissions. A report on low carbon travel and tourism has been produced by the **World Economic Forum, 2009**. The report mentioned that travel

## Original Article

and tourism excluding aviation is responsible for about 3% of GHG emissions while aviation contributes 2% of global manmade emissions.

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The report proposes various carbon emission mitigation measures including: a) Development and deployment of low carbon emission fuels in the aviation sector, b) Deployment of renewable energy technologies in tourist accommodation, and c) Improvements in cruise ship fuel efficiency, changes in modal-shift from cars to mass transit systems (bus and rail) and de-carbonization of car transport.

A report on global de-carbonization of the hotel industry has been published by the **International Tourism Partnership, 2017**. According to this report the global hotel industry should reduce its greenhouse gas emissions per room per year by 66% from 2010 levels by 2030 and by 90% by 2050. The report mentions that the technology exists today to fully de-carbonize the hotel industry while several opportunities exist for evolving to the next generation, thinking about sustainability including the transformation of the hotel sector to be more energy efficient, more renewable and more electrified. **WWF, 2008** has reported on environmental impacts of holiday trips expressed as CO<sub>2</sub> equivalents. The report has developed a calculation method for CO<sub>2</sub> emissions due to tourism including: a) travel to and from the destination, b) accommodation, c) food and d) activities. Comparing the carbon footprint in seven indicative trips using car, train, bus and airplane, the report concluded that air transport is a major contributor in CO<sub>2</sub> emissions in tourism while the CO<sub>2</sub> equivalent emissions in these seven trips varied between 18.4 and 515.6 KgCO<sub>2</sub> per person per day. Calculations in this report indicated that the choice of transport to and from the destination is by far the most influential factor in a given vacation's carbon footprint. A report on climate change and tourism has been released by **UNEP, 2008**. According to this report, air transport causes 87% of total carbon emissions in international trips while average carbon emissions in accommodation are at 15.6 kgCO<sub>2</sub>/p.n.s., although this varies among different types of tourist accommodation. Air transport in distances < 500 km emit 0.206 kgCO<sub>2</sub> per km per passenger, for distances between 1,500-2,000 km, 0.111 kgCO<sub>2</sub> per km per passenger, and for distances > 2,000 km, 0.121 kgCO<sub>2</sub> per km per passenger. Few data are available for carbon emissions in various tourist activities and the report stated for international tourists an average value of 27 kgCO<sub>2</sub> per trip. The report also mentioned that the average global tourist carbon emissions are 250 kgCO<sub>2</sub> per trip although this figure varies significantly between international and local trips.

### 2.2 Carbon emissions due to tourism in various countries

**Wu et al, 2011** have reported on energy consumption and CO<sub>2</sub> emissions in the tourism sector in China. The authors estimated that energy consumption in the Chinese tourism industry accounts for 0.51% of the annual energy consumption while tourism related CO<sub>2</sub> emissions account for 0.86% of the total emissions in the country. They concluded that tourism is a low-carbon emissions industry. **Huang et al, 2016** have reported on carbon emissions due to tourism in Hubei province, China. The authors calculated that travel transportation accounts for about 95.7% of total carbon emissions in Hubei province. They mentioned that this figure is higher than the world proportion, which is around 90% and the national proportion reported at 67.72%. They found that carbon emissions in tourism transportation in Hubei province are mainly due to expressway transportation and additionally to civil aviation transportation. **Dwyer et al, 2010** have estimated the carbon footprint of Australian

## **Original Article**

tourism. The authors reported that tourism contributes 5.3% of total industry GHGs in Australia. Among various tourism sectors, the share of domestic air transport is at 56.68%, of accommodation at 9.22%, of non-air transport at 6.62%, of food and drink at 2.84%, of shopping at 7.05% and of all other activities at 17.59%. **Smith et al, 2008** have reported on carbon emissions offset due to international air travel to and from New Zealand. The authors have calculated the carbon emissions from international visitors in New Zealand residents travelling overseas. Investigating various carbonoffsetting technologies which are technically feasible, cost-effective and realistic in New Zealand to compensate for these carbon emissions, they concluded that offsetting schemes operating outside of New Zealand's territory would be required for that. **Perch-Nielsen et al, 2010** have investigated the GHG intensity (GHG emissions to the generated income) of the tourism sector in Switzerland. Their results indicated that the Swiss tourism sector is more than four times more GHG-intensive than the Swiss economy on average. The authors also mentioned that the share of air transport GHG emissions to the total tourism GHG emissions was at 80%, of accommodation at 10%, of other transport at 7%, of food and beverages at 2% and of other activities at 1%. **Sharp et al, 2016** have estimated the carbon footprint of inbound tourism in Iceland. The authors mentioned that tourism is the fastest growing industry in the country and tourism-induced emissions during 2010-2015 have tripled. They also stated that almost all tourists arrive in Iceland by plane while aviation accounts for 50-82% of all tourism GHG emissions. The authors estimated that the carbon footprint for the average tourist in this country is at 1.35 tons of CO<sub>2</sub>-eq while it ranges from 1.1 to 3.2 tons of CO<sub>2</sub>-eq. **Becken et al, 2006** have estimated national CO<sub>2</sub> emissions from tourism in New Zealand. The authors used top-down and bottom-up analysis, stating that both approaches gave similar results. They estimated that the average international visitor in the country had a carbon footprint, from accommodation, domestic transport and activities, at 0.26 tons CO<sub>2</sub> without including the emissions due to international flights.

**Becken et al, 2003** have studied the energy use associated with different travel choices in New Zealand. The authors mentioned that international tourists consume four times more energy than domestic tourists while the share of transportation in the total energy consumption is at 65-73%. They also stated that for international tourists, transportation contributes at 65.25% of their total energy use, accommodation at 21.68% and various other activities at 13.07%. **Wang et al, 2017** have reported on progress and prospects for tourism footprint research. The authors stated that two methods have been used for measuring the tourism footprint including top-bottom and bottom-up approaches.

They also mentioned that various researchers have considered various parts of tourism in order to estimate its footprint including transportation, accommodation, catering, shopping, entertainment, sightseeing and waste disposal. Additionally, the authors stated that there is a lack of a common agreed method among researchers for estimating the tourism footprints. **Lenzen et al, 2018** have reported on the carbon footprint of global tourism. The authors stated that carbon footprint of tourism accounts for about 8% of the global GHG emissions. They disagree with the popular mindset that tourism is a low-carbon activity. On the contrary, they mentioned that it is accompanied with a high environmental burden. They also stated that the existing mitigation strategies including encouragement of travelers to choose short destinations using public transportation and increasing the energy and carbon efficiency of tourism enterprises have not proved so far effective in reducing its carbon footprint. **Farreny et al, 2011** have reported on carbon dioxide emissions of Antarctic tourism. The authors stated that CO<sub>2</sub> emissions are produced from international flights and from cruises. They estimated the average CO<sub>2</sub> emissions at 0.49 tons

## **Original Article**

CO<sub>2</sub> per passenger per day while 70% of these emissions are attributable to cruising and 30% to flying. **Gosling et al, 2007** have reported on carbon offsetting schemes for aviation. The authors mentioned that tourism is dependent on air transport while the obligations to reduce GHG emissions might make air transport more expensive. Voluntary carbon offsetting measures could help to stabilize or reduce emissions due to aviation. Carbon compensation measures include either its sequestration in biomass or replacement of fossil fuels with renewable energies and increase of energy efficiency in energy systems. The authors concluded that despite aviation being of central importance for international tourism, voluntary carbon offsetting schemes remain an ambiguous solution to aviation's environmental impacts. **Hall et al, 2013** have reported on the primacy of climate change for sustainable international tourism. The authors mentioned that international tourism is an important contributor to sustainable development strategies. However, its impacts to climate change are not negligible. Examining the behavior of the main players, they stated that consumers are not willing to restrict or give up international tourism while governments have not agreed on a global framework for emission reductions. Additionally the international air transport association considers that carbon neutral aviation can be achieved only in the medium term, within 50 years. **Jardine, 2009** has reported on carbon dioxide emissions of flights. The author mentioned that there are different procedures and methodologies for estimating carbon emissions of air transport which depend on the distance and the type of airplane. He stated that DEFRA's methodology proposes emission factors of 0.158, 0.1304 and 0.1056 kg CO<sub>2</sub> per km travelled for short, medium and long haul flights respectively. The author proposes on average a carbon emission value for air transport at 0.08 kg CO<sub>2</sub> per seat per km. **Meng et al, 2016** have studied the direct and indirect carbon emissions of the Chinese tourism industry. The authors stated that indirect carbon emissions in tourism are higher than the direct emissions. Compared with the manufacturing industry, the tourism industry in China is a low energy consumption industry. They also mentioned that, in 2010, transport had a share of 69.55% in total direct carbon emissions in tourism, sightseeing at 1.55%, accommodation and food at 10.63%, shopping at 10.33% and other sectors at 7.93%. **Gossling, 2013** has reported on national emissions from tourism. The author stated that studies regarding national emissions from tourism are difficult to be compared since they use different methodologies. The fact that bunker fuels, used in airplanes and ships, are not included in national GHG inventories results in an underestimation of national carbon emissions from tourism. He also mentioned that carbon emissions vary depending on national and international trips. In Germany emissions for national trips are 183 kgCO<sub>2</sub>/trip while for outbound holidays they are 672 kgCO<sub>2</sub>/trip, with an average value at 345 kgCO<sub>2</sub>/trip. **Gossling, 2000** has reported on energy use in tourism in developing countries. The author stated that for a typical two-week package tour in a developing country, about 24% of the fossil fuels used can be attributed to the destination share. However the major amount of energy use, approximately 76%, is used for air travel. He also mentioned that since aviation emissions are released into the lower and upper troposphere they have a larger impact on climate change than emissions released at the earth's surface.

### **2.3 Tourism in the island of Crete, Greece**

**MAICh has created a tourism observatory in Western Crete and it has reported on tourism in Crete, 2018.** The report mentioned that over 5 mil. tourists arrive in Crete every year while approx. 2 mil. of them arrive in Western Crete. International arrivals at Chania airport in 2017 were 1,102,000 while tourists stayed in Crete on average for 9 days. The report also stated that the share of the tourism sector in the GDP of the island was

## **Original Article**

47%. **Hammami et al, 2018** have investigated the tourist's behavior towards local Cretan food. The authors have implemented an empirical study using questionnaires with international tourists at the airport of Chania, Crete regarding their perception of Cretan food tasted during their stay on the island. Their results indicated that tourists were satisfied with local gastronomy, increasing their intention to revisit Crete in the near future. Preference and use of local food, instead of imported which requires transport to Crete, decreases the carbon footprint of international tourism to Crete. A report on **building regional actions for new development in tourism in the region of Crete has been published, 2017**.

The report mentioned that in 2016, 3,938,580 passengers arrived by air with International flights in Crete while 963,614 passengers arrived by sea. 728,298 of them arrived with internal shipping lines, while the rest came with foreign cruises. Additionally 833,581 passengers arrived in Crete during 2016 with domestic flights. **Vourdoubas, 2016** has reported on energy consumption and carbon emissions in hotels in Crete, Greece. The author stated that energy analysis in five summer-operating hotels in Crete indicated that their average annual energy consumption was 19.4 KWh/per night spent (p.n.s) while their annual CO<sub>2</sub> emissions were at 12.1 kgCO<sub>2</sub>/p.n.s. **Vourdoubas, 2018** has investigated the possibility of creating net zero carbon emissions hotels in the Mediterranean region. The author mentioned that low carbon emissions hotels can be achieved with the combined use of various renewable energy technologies. He proposed that the use of solar thermal energy, solar-PV energy and high efficiency heat pumps in hotels could zero their net carbon emissions due to energy use. The **Greek Statistics Organization, 2018** has reported on tourism in Greece during 2018. The report mentioned that during 2017, 73,474,000 overnight stays of foreign tourists and 14,154,000 for domestic tourists were recorded in Greece. In the island of Crete, during the same year, 23,609,000 overnight stays of foreign tourists and 907,000 of domestic tourists were recorded.

### **The aims of the current work are:**

- a) Estimation of carbon emissions due to international tourism in Crete,
- b) Estimation of carbon emissions due to different tourism sectors, and
- c) Comparison of carbon emissions of tourism in Crete with carbon emissions in other countries.

Use of available data on tourist arrivals in Crete, modes of their transport, countries of origin and their total overnight stays on the island combined with data related with their carbon emissions in transport, accommodation and in other activities have been used for estimations. Existing data are limited and dispersed in few studies for different years while, to my best knowledge, previous studies for carbon emissions due to tourism in Crete have not been reported.

### **3. Carbon emissions due to tourism**

Tourism like other industries requires energy and contributes to GHG emissions. It is estimated that tourism generated GHG emissions correspond approximately to 5% of the global anthropogenic GHG emissions. Energy is consumed during international and domestic transport, accommodation, catering, sightseeing, various activities and in waste disposal. Carbon emissions in tourism differ significantly depending on the origin of the tourists and the mode of transport, with international tourists having higher energy consumption and carbon emissions than domestic tourists. Carbon emissions also differ significantly among different sectors of tourism with international transportation having a higher share to the total carbon emissions. Various methodologies have been proposed for estimating carbon emissions in tourism using either top-bottom or bottom-up approaches.



## Original Article

However there is no common agreed methodology worldwide for estimating these emissions. Total carbon emissions due to tourism according to various studies are presented in Table

**Table 3.1 Carbon emissions due to tourism in various countries.**

Authors	Country	Carbon emissions
Sharp et al, 2016	Iceland	1,350 kgCO <sub>2</sub> per trip
Becken et al, 2006	New Zealand	260 kgCO <sub>2</sub> per trip without including international flights
WWF, 2008	Globally	18.4-515.6 kgCO <sub>2</sub> per tourist per day
Farreny et al, 2011	Antarctic	490 kgCO <sub>2</sub> per tourist per day
Gossling, 2013	Germany	183-672 kgCO <sub>2</sub> per trip Average 345 kgCO <sub>2</sub> per trip
UNEP, 2008	Average global	250 kgCO <sub>2</sub> per trip

### 4. Tourism in Crete

Crete is a major and popular tourist destination in the Mediterranean region while tourists arrive in the island by airplane and by ship. Total tourist arrivals in 2016 were 5,318,984 with the majority of them, at 81.88%, arriving by airplane. Taking into account that the population of the island was 621,340 inhabitants (recent census in 2011), there were 8.56 visitors per local inhabitant during 2016. Tourist arrivals in Crete with various transport modes during 2016 are presented in Table 4.1.

**Table 4.1. Tourist arrivals in Crete with international flights, domestic flights and ships (2016)**

Mode of transport	Number of tourists	%
Number of tourists arriving with international flights <sup>1</sup>	3,938,580	74.04
Number of tourists arriving with domestic flights <sup>1</sup>	416,790	7.84
Number of tourists arriving with airplanes <sup>1</sup>	4,355,370	81.88
Number of tourists arriving by ship <sup>1</sup>	963,614	18.12
Total number of tourists arriving to Crete <sup>1</sup>	5,318,984	100

<sup>1</sup> Source: Region of Crete, Regional survey, 2017

### 5. Estimation of carbon emissions from international tourism in Crete

Carbon emissions from international tourism in Crete are estimated from the sum of emissions due to transportation, accommodation and various tourist activities. Various empirical data have been used for estimating these carbon emissions.

#### 5.1 Carbon emissions due to air and sea transport

International tourists use international flights, domestic flights and sea transport for their arrival in the island. Crete has three international airports and six main ports used by tourists. Assuming that 50% of the arrivals by domestic flights in Crete are attributed to tourism, the number of tourist arrivals by domestic flights in Crete in

## Original Article

2016 were 416,790. Taking into account that the majority of the international flights arriving to Crete depart from Scandinavian countries, Germany and England, the average distance of each international flight has been assumed at 2,000 km. Since the domestic flights and the ships depart from Athens, the average distance to Crete has been assumed at 300 km. The average distance of tourists arriving in Crete with different transport modes is presented in Table 5.1.1., while carbon emissions due to air and sea transport are presented in Table 5.1.2.

**Table 5.1.1 Average distance of tourists arriving to Crete**

Average distance covered by airplane for international tourists arriving to Crete <sup>1</sup>	4,000 km
Average distance of domestic flights arriving to Crete <sup>1</sup>	600 km
Average distance of ships in domestic lines arriving to Crete <sup>1</sup>	600 km

<sup>1</sup> Incoming and return

**Table 5.1.2. Carbon emissions from air and sea transport**

Carbon emissions from air transport in short distances <sup>1</sup>	0.158 kgCO <sub>2</sub> per km and passenger
Carbon emissions from air transport in long distances <sup>1</sup>	0.110 kgCO <sub>2</sub> per km and passenger
Carbon emissions from sea transport in short distances <sup>2</sup>	0.115 kgCO <sub>2</sub> per km and passenger

<sup>1</sup> Source: Jardine, 2009

<sup>2</sup> Source: 2008 Guidelines to Defra's GHG conversion factors

Carbon emissions due to tourist arrivals in Crete with various transport modes are estimated by multiplying the number of tourist arrivals by the average distance of travelling and by the unit emission factor in each transport mode. The total carbon emissions are the sum of emissions with each transport mode. Carbon emissions due to tourist arrivals in Crete in 2016 with various transport modes are presented in Table 5.1.3.

**Table 5.1.3. Carbon emissions due to tourist transport by air and sea in Crete (2016) <sup>1</sup>**

Carbon emissions due to tourists arriving with domestic flights	39,512 tonsCO <sub>2</sub>	2.15%
Carbon emissions due to tourists arriving with international flights	1,732,975 tonsCO <sub>2</sub>	94.23%
Carbon emissions due to tourists arriving with ships	66,489 tonsCO <sub>2</sub>	3.62%
Total carbon emissions from tourists in Crete	1,838,976 tonsCO <sub>2</sub>	100%
Average carbon emissions due to transport in Crete	346 kgCO <sub>2</sub> per trip	

<sup>1</sup> Source: own estimations based on data in tables 4.1, 5.1.1 and 5.1.2

## Original Article

### 5.2 Carbon emissions due to accommodation

Tourists are hosted in different types of accommodation consuming energy during their stay. Energy consumption and carbon emissions depend on the type of accommodation. The number of overnight stays of tourists in Crete is presented in Table 5.2.1.

**Table 5.2.1. Overnight stays of tourists in various accommodation types in Crete (2017)**

International tourists	23,609,000 overnight stays
National tourists	907,000 overnight stays
Total number in Crete	24,516,000 overnight stays
Percentage to the overnight stays in Greece	27.5%
Overnight stays of tourists in Crete	4.61 days

Source: Greek Statistics office, 2018

There is a large incompatibility between the number of overnight stays of tourists in Crete given by the Greek Statistics office and the number of overnight stays estimated from the total number of visitors and the average period of their stay in Crete as reported in other studies (**Angelakis, 2018**). This is probably due to the fact that a large number of tourists stay in Crete in various non-typical accommodation types which are not recorded by the Greek Statistics office. Total carbon emissions due to accommodation are estimated by multiplying the number of overnight stays with the carbon emissions per night spent. Carbon emissions due to tourist accommodation in Crete are presented in Table 5.2.2.

**Table 5.2.2. Carbon emissions due to tourist accommodation in Crete**

Carbon emissions per tourist per overnight stay in Crete <sup>1,2</sup>	12.1 kgCO <sub>2</sub> per night spent
Total carbon emissions in tourist accommodation in Crete	296,643.6 tonsCO <sub>2</sub>
Carbon emissions due to accommodation in Crete	55.77 kgCO <sub>2</sub> per trip

<sup>1</sup> Source: Vourdoubas, 2016, <sup>2</sup> Carbon emissions in accommodation have been estimated in summer operating hotels in Crete

### 5.3 Carbon emissions due to other tourist activities

Data on carbon emissions from other tourist activities in Crete are not available. It has been assumed that these emissions are at 27 kgCO<sub>2</sub> per trip (UNEP, 2008). Total carbon emissions due to tourism in Crete are estimated from the sum of the emissions due to transport, accommodation and other activities, and they are presented in Table 5.3.1.

**Table 5.3.1. Total carbon emissions due to tourism in Crete**

Tourism sector	Carbon emissions (kgCO <sub>2</sub> per trip)	% of total
Transport	346	80.69
Accommodation	55.77	13.01



## Original Article

Other activities	27	6.30
Total	428.77	100

Therefore the total annual carbon emissions due to 5,318,984 tourists visiting Crete in 2016 were 2,280.62 ktCO<sub>2</sub>. However 80.69% of these emissions, at 1,840.37 ktCO<sub>2</sub>, are not included in the national inventories due to the fact that they are produced from bunker fuels used in tourist's arrival. Taking into account that, according to the last census in 2011, the population of Crete was 621,340 inhabitants (Region of Crete, BRANDTOUR, 2017) and the CO<sub>2</sub> emissions per capita in Greece (2014) were 6.2 ton CO<sub>2</sub> (Worldbank), it is concluded that the total CO<sub>2</sub> emissions in Crete (2014) were 3,852.3 ktCO<sub>2</sub>. Therefore the total carbon emissions due to tourism in Crete, estimated in the present study, including emissions due to international flights, correspond at 59.20% of the total CO<sub>2</sub> emissions in the island in 2014. Annual carbon emissions per capita due to tourism in Crete are presented in Table 5.3.2.

**Table 5.3.2 Annual carbon emissions due to tourism in the island of Crete, Greece (tonsCO<sub>2</sub> per capita)**

Annual carbon emissions due to bunker fuels used in tourist's arrival	2.96 tonCO <sub>2</sub> per capita
Annual carbon emissions due to tourism in Crete excluding bunker fuels used in tourist's arrival	0.71 tonCO <sub>2</sub> per capita
Total annual carbon emissions due to tourism in Crete	3.67 tonCO <sub>2</sub> per capita
Total annual carbon emissions in Crete	6.20 tonCO <sub>2</sub> per capita
Share of carbon emissions due to bunker fuels used in tourist's arrival	47.74%
Share of carbon emissions due to tourism, excluding emissions from bunker fuels used in tourist's arrival, to total carbon emissions in Crete	11.45%
Share of carbon emissions due to tourism to total carbon emissions in Crete	59.19%

## 6. Discussion

There is a lack of available data regarding carbon emissions from tourism in Greece. Data available on tourist arrivals (2016), on overnight stays (2017) and for carbon emissions in accommodation (2014-2015) have been used. However, overnight stays from tourists in Crete are probably underestimated due to the fact that various non-typical tourist accommodations, which are broadly used, are not recorded by the statistics office. This results in an incompatibility regarding the average time of tourist stays in the island as estimated in the current study (4.61 days), and reported for international tourists arriving in Western Crete (approximately 9 days, Angelakis, 2018). Due to the lack of data concerning the tourist arrivals from domestic flights, it has been assumed that 50% of the passengers are tourists. Assumptions have also been made regarding the average distance of international flights based on the available data concerning the nationality of the visitors in the island. The estimated carbon emissions from accommodation in Crete at 12.1 kgCO<sub>2</sub>/p.n.s. is close to the average global value reported, at 15.6 kgCO<sub>2</sub>/p.n.s. (UNEP, 2008). The share of carbon emissions due to international flights arriving and departing in Crete, at 80.69%, is close to the average global value at 75% (UNWTO, 2017), to the value reported by Gossling, 2000, at 76%, and to the value reported for international trips, at 87% (UNEP, 2008). However the impact of the

## **Original Article**

fossil fuels used in international flights on the climate are higher than the percentage reported due to the fact that the GHGs are released in the troposphere and not in the earth's surface, increasing their climate footprint. Carbon emissions from tourism can be distinguished as direct and indirect emissions while various studies indicated that indirect emissions are higher than the direct.

### **7. Conclusions**

Annual visitors in Crete during 2018 were 5,318,984, exceeding more than eight (8) times the permanent inhabitants of 621,340 on the island. Most of them, 74.04% of the total, arrived in Crete with international flights. Carbon emissions due to international tourism in Crete, Greece have been estimated at 428.77 kgCO<sub>2</sub> per trip, which corresponds to 3.67 tonCO<sub>2</sub> per capita in the island, compared with total carbon emissions in Crete at 6.2 ton CO<sub>2</sub> per capita. Annual carbon emissions due to tourism in Crete, including international flights, correspond to 59.19% of total annual carbon emissions per capita in Crete. International flights have the highest contribution in total carbon emissions due to tourism in Crete. The share of transport in total carbon emissions is 80.69%, of accommodation 13.01% and of other activities 6.30%. Among various transport modes used in tourist arrivals in Crete, emissions due to international flights have a share at 94.23% to total emissions due to transport, followed by emissions due to ship arrivals at 3.62%, and by emissions due to domestic flights at 2.15%. These results indicate that the most efficient and appropriate way to reduce carbon emissions in Crete due to tourism is to reduce their emissions in the international flights. Estimated carbon emissions in Crete at 428.77 kgCO<sub>2</sub> per trip are higher than the average global value reported by UNEP, 2008, at 250 kgCO<sub>2</sub> per trip, and by Gossling, 2013 for Germany at 345 kgCO<sub>2</sub> per trip; but they are lower than the value reported by Sharp, 2016 for Iceland at 1,350 kgCO<sub>2</sub> per trip. The share of transport to the total carbon emissions in Crete at 80.69% is between the values reported by UNEP, 2008 for international trips at 87% and by UNWTO, 2017 for international tourism at 75%. Further work should be focused in the investigation of various approaches for offsetting carbon emissions due to tourism in Crete. Additionally, the estimation of carbon intensity of tourism in Crete and its comparison with carbon intensity in other industries will give some indications regarding its contribution and its future role in the development of a low carbon economy.

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**Original Article**

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