Energy and Environment Research; Vol. 9, No. 2; 2019
ISSN 1927-0569 E-ISSN 1927-0577
Published by Canadian Center of Science and Education

Mitigation and Compensation of CO_2 Emissions Due to International Tourism in the Island of Crete, Greece

John Vourdoubas[1]

[1] Mediterranean Agronomic Institute of Chania, Chania, Crete, Greece

Correspondence: John Vourdoubas, Mediterranean Agronomic Institute of Chania, Chania, Crete, Greece. Tel: 30-282-1035-020. E-mail: vourdoubas@chania.teicrete.gr

Received: August 29, 2019 Accepted: October 24, 2019 Online Published: November 20, 2019

doi:10.5539/eer.v9n2p61 URL: https://doi.org/10.5539/eer.v9n2p61

Abstract

The purpose of the current study is to examine the possibilities of mitigating the carbon footprint of the tourism industry in Crete, Greece, to estimate its carbon intensity and additionally the cost of eliminating all tourism-related carbon emissions with compensation credits in the island. Various mitigation options in different sectors of the tourism industry in Crete, including transport to the destination, accommodation, catering and various tourist activities at the destination, have been proposed. Mitigation of carbon emissions in accommodation is easier, due to the presence of appropriate technologies, than in other tourism sectors. Various carbon offsetting schemes including the use of carbon compensation credits and forest restoration have also been investigated. Based on existing research regarding annual CO_2 emissions due to the tourism industry in Crete, the area of new forest plantations required for offsetting all tourism-related carbon emissions in Crete has been calculated at 114 031 ha. The carbon intensity of the tourism industry in Crete has been estimated at 0.562 $kgCO_2$/€ which is in the same range of values reported for other EU countries. The annual cost of eliminating all tourism-related CO_2 emissions in Crete has been estimated at €20,525,580 which corresponds to 0.51% of the annual gross domestic product in the island attributed to tourism.

Keywords: Carbon emissions, carbon offsetting, climate change, Crete, Greece, tourism industry

1. Introduction

The necessity to mitigate climate change requires the radical change of the technology used and the human behavior in all sectors of the economy. Tourism is currently a growing and expanding industry which contributes significantly in the increase of emissions of greenhouse gases (GHGs) in the atmosphere, increasing the anthropogenic climate change. The highest share of carbon emissions in the tourism industry is due to air transportation. Energy is consumed during tourists' transportation to the destination, in accommodation and in various activities at the destination. The international tourism industry consumes mainly fossil fuels while the use of renewable energies so far is rather limited. Mitigation of climate change due to the tourism industry can be achieved with various ways including changes in the technology and the fuels used, selection of vacations with a lower carbon footprint and by offsetting its carbon emissions with various schemes. The concept of carbon neutral tourism destinations has attracted a lot of attention, recently aligned with the idea of transition to a low-carbon and more environmentally sustainable economy. Changes in the tourists' behavior, increasing their awareness regarding the impacts of their holidays on climate change and their voluntary mitigation of their carbon footprint with various offsetting schemes could improve the environmental performance of the tourism industry, reducing its impacts on climate change. Complying with carbon mitigation requirements agreed during the international summit in Paris in 2015 requires a sharp decrease of the current emissions in the tourism industry. Although Crete is a well-known and popular tourist destination all over the world, published research regarding the possibilities of mitigating and compensating tourism-related GHG emissions in the island is currently lacking.

2. Literature Survey

2.1 Tourism and Climate Change

Yang (2010) has reported on the development of tourism in the low carbon economy. The author proposed various measures which could promote low carbon tourism. These include: a) Minimization of tourism

overloading of sensitive ecosystems, b) Reduction of direct carbon emissions caused by transport, c) Reduction of fossil fuels use and carbon emissions in tourism accommodation, d) Improving service quality and promotion of products and services with low carbon impacts, and e) Changing inappropriate tourist behavior. Gossling et al. (2010) have studied the future of tourism regarding the perspective of climate change mitigation. The authors stated that technology and management improvements in tourism are not sufficient to achieve even modest emission reductions in the sector. They concluded that radical changes are required for reconciliation of the increasing demand in tourism from an increasing world population with climate policy targets. Huang et al. (2011) have presented a model for developing low carbon tourism. The model that the authors have developed is based on the creation of low carbon tourist attractions, in the allocation of low carbon tourism facilities, in promoting a low carbon form of tourism consumption and in nurturing a tourism experience environment of carbon sequestration. Zeppel (2012) has reported on collaborative governance for low carbon tourism in Australia. The author has mentioned that implementing climate change activities in Australia requires cooperation among tourism agencies, business programs, carbon consultants and offset providers. He stated that climate change initiatives of tourism agencies regarding governance are based on accountability, transparency, involvement, structure, effectiveness and power. Hares et al. (2010) have reported on the air travel decisions of UK tourists. The authors have investigated the influence of climate change on holiday travel decision. Their findings indicated three barriers regarding climate impacts on tourists when preparing their holidays. These include the dismissal of alternative transport modes to air travel, their refusal to make changes in their holidays due to climate change reasons and their denial to accept personal responsibility for the impacts of their holidays on climate change. A guide on carbon-neutral tourism based on the implementation of an EU-funded LIFE project has been reported in 2012. The guide offers advice and guidance to tourists on how they can reduce their carbon footprint during their holidays. This advice includes: a) Choosing the greenest way to travel to the destination, b) Preference to move in the destination with public transportation instead of hiring cars, c) Trying to minimize energy consumption while staying in the accommodation, and d) Trying to offset carbon emissions voluntarily by participating in a carbon-offsetting trading scheme. Dubois et al. (2011) have investigated the future tourism mobility and its impacts on climate change. The authors stated that in 2005, tourism was responsible for around 5% of all global CO_2 emissions, of which 75% were caused by passenger transport. They mentioned that the necessity for a sharp reduction in carbon emissions, including trading schemes and/or offsetting, could only be achieved to a moderate level, with substantial changes in the way that we travel. Gössling (2009) has reported on carbon-neutral tourism destinations. The author presented the concept of "carbon neutrality" for tourism destinations, mentioning that an increasing number of destinations plan to become "carbon-neutral" enhancing their image as being environmentally sustainable. Gössling et al. (2010) have reported on the implementation of carbon-neutral tourism destinations with reference to the Seychelles islands. The authors have presented a methodology promoting carbon-neutral tourism policies. Their methodology included offsetting of carbon emissions due to air transport which accounts for approximately 86% of total carbon emissions due to tourism in the Seychelles. Accommodation, they stated, accounts for 12% of total carbon emissions caused by tourism which can be partly reduced with the increase of energy efficiency and the use of renewable energy sources (RES), and the rest with carbon-offsetting measures. Perch-Nielsen et al. (2010) have investigated the GHG intensity (GHG emissions to the generated income) of the tourism sector in Switzerland. The authors mentioned that GHG intensities of the tourism sector in UK, Spain, Sweden and Switzerland vary between 0.44 $kgCO_2/€$ and 0.85 $kgCO_2/€$.

2.2 Voluntary Carbon Offsetting by Tourists

Gössling et al. (2007) have reported on voluntary carbon offsetting schemes in aviation. The authors mentioned that tourism is becoming increasingly dependent on air transport with significant contributions to GHG emissions. They concluded that an optimal solution for mitigating carbon emissions in aviation might be a combination of compulsory non-tradable measures on aviation-related emissions with voluntary schemes. Becken (2004) has investigated the perception of tourists and tourist experts on climate change and on carbon-offsetting schemes in Australia and in New Zealand. The author realized surveys questioning travelers if climate change is an issue and if tourists were willing to participate in tree-planting activities. Her results indicated that tourists were willing to be involved in tree-planting activities while tourism experts did not consider that carbon emissions due to tourism activities were contributing to climate change. Gössling et al. (2009) have reported on voluntary carbon offsets by Swedish air travelers. The authors mentioned that tour operators and airlines are offering voluntary carbon-offsetting schemes. However, they stated, customers have shown limited interest in these schemes and the overall amount of emissions offset remains negligible. McKercher et al. (2010) have examined the attitudes towards voluntary carbon emission reductions in tourism among residents of Hong Kong. Their findings indicated that regular international tourists were aware about the

impacts of tourism on climate change but they were less willing to alter their behavior. The authors also stated that similar behavior was identified in other relevant studies. Becken (2013) has reviewed the relation of tourism and climate change as an evolving knowledge domain. The author stated that research on tourism and climate change has grown substantially over the last 26 years. Her research was focused on how climate change will impact on tourism and on how tourism-related carbon emissions could be mitigated. She also mentioned that this research field is characterized by a small number of researchers who are co-authors in a large number of publications. Velonaki et al. (2015) have reported on responsible tourism behavior in the 21st century. The authors mentioned their research examining interactions between airline corporate social responsibility policies and travelers' attitudes towards voluntary carbon emissions. They also stated that probably financial responsibility for offsetting CO_2 emissions in travelling should be shared between passengers and airline companies. Dodds et al. (2008) have studied the awareness of travelers and travel agents in carbon offsetting in Toronto, Canada. The authors stated that their results indicated a lack of awareness of carbon offsetting caused by air travel. Zeppel et al. (2013) have explored the carbon offsetting behavior of environmentally certified tourism enterprises located in Queensland, Australia. Their findings revealed that carbon offsetting was not as popular as other carbon mitigation actions such as reducing energy use and improving energy efficiency. The authors mentioned that more than one-third of the examined enterprises indicated that they did not believe that carbon offsetting was necessary for their businesses. Juvan et al. (2014) have studied the attitude of travelers to consider the climate impact of their holidays. The authors have implemented empirical studies with 261 potential travelers in Australia and Slovenia who expressed their difficulties in assessing without assistance the climate impacts of their vacations. They suggested that the tourism industry should provide travelers with reliable and user-friendly information regarding the carbon footprint of their holidays. Mair (2011) has investigated air travelers' voluntary carbon-offsetting behavior in Australia and the UK. Her results indicated that air travelers who purchase voluntary carbon-offsetting credits have pro-environmental and eco-centric behavior and attitudes.

2.3 Mitigation and Compensation of Carbon Emissions in the Tourism Industry

Smith et al. (2009) have investigated carbon emission offsets for aviation-generated emissions in New Zealand. The authors have studied five technical carbon-offsetting schemes for international tourists in New Zealand including: a) Use of energy-efficient lighting, b) Creation of wind farms replacing thermal generation stations, c) Reduction of road transport, d) Regeneration and planting of new forests, and e) Increase of thermal generation efficiency. They concluded that a single carbon-offsetting scheme, targeted inside the country, is physically and/or politically unrealistic. Becken (2005) has studied harmonization of climate change mitigation and adaptation in the Fiji islands. The author stated that these islands are highly vulnerable to climate change and various adaptation measures have been taken. She also mentioned that there are some isolated examples in the tourism industry which use the appropriate technology and management for mitigating their impacts in climate change. Zhang et al. (2018) have studied, with simulation techniques, the impacts of a carbon tax on tourism-related CO_2 emissions and economic welfare in China. The authors stated that their findings indicated that a carbon tax policy could have a remarkable impact on tourism-related carbon emissions and economic welfare. They suggested that, preferably, tourism industries should be encouraged to reduce CO_2 emissions by using clean energy and low-carbon energy technologies. Eijgelaar (2011) has reported on voluntary carbon offsetting for reducing tourism emissions. The author mentioned that tourism and aviation industries have not managed to reduce carbon emissions like other industries have done. He stated that the potential of voluntary carbon offsetting for reducing tourism transport emissions is rather low while current sales of flight offsets are less than 1% of all carbon emissions. Higham et al. (2015) have investigated the possibility of radical carbon emissions reductions due to tourists' air travel. The authors stated that future projected growth in aviation is incompatible with the necessity of radical carbon emissions reduction. They have implemented an empirical analysis with questionnaires in four countries investigating the willingness of travelers to accept voluntary measures aiming to reduce tourism-related carbon emissions. Their results indicated that Norwegians were willing to accept governmental regulation to air travel while travelers from the UK, Germany and Australia did not accept strategies resulting in the restriction of their freedom to travel. Gössling et al. (2015) have reported on inter-market variability in CO_2 emission intensities in tourism in eleven countries between 1995 and 2010. Their results indicated variations in inter-market emission intensities of up to a factor of 30 at 127-3930 kgCO_2 per tourist. The authors discussed the potential for reducing emissions from tourism fostering specific markets. Vourdoubas (2018) has studied the technical and economic feasibility of net zero-carbon emission hotels due to energy use in the Mediterranean region. The author stated that low/zero-carbon emission hotels can be achieved in this area with the combined use of various renewable energy technologies including solar thermal, solar photovoltaic and high efficiency heat pumps. He also mentioned that these technologies are currently reliable, cost-effective and broadly used in many applications. Vourdoubas (2019) has estimated the carbon emissions due

to tourism in the island of Crete, Greece. The author estimated the annual carbon emissions per tourist in Crete at 488.77 $kgCO_2$ while he stated that 80.69% of all tourism-related carbon emissions are attributed to their incoming and return transportation by air and sea. Total CO_2 emissions in 2016 have been estimated at 2280.62 $ktCO_2$. Without incoming and return international tourist transportation to Crete, their total annual CO_2 emissions were estimated at 440.39 $ktCO_2$. Toochi (2018) has studied carbon sequestration by forests. The author mentioned that forests are cost-effective as CO_2 absorbers while tropical forests may absorb more CO_2. He also stated that maple-beech-birch forests could absorb annually 1973-4382 $kgCO_2$ per ha while white and red pine forests absorb 8425-11 015 $kgCO_2$ per ha. Bernal et al. (2018) have reported on CO_2 removal rates from forest restoration activities. The authors stated that planted forests had the highest annual CO_2 removal rates, ranging from 4.5 to 40.7 tCO_2 per ha. They also mentioned that mangrove tree restoration was the second more efficient with annual CO_2 removal rates up to 23.1 tCO_2 per ha while annual CO_2 removal rates in natural regeneration varied between 9.1 and 18.8 tCO_2 per ha. A report on using forest carbon credits to offset emissions in the downstream business has been published by the Concawe air quality management group (2017). The report stated that prices for forest carbon credits vary from on average US$ 4 to US$ 10 per tCO_2 while afforestation and reforestation projects average at US$ 8 per tCO_2. It also mentioned that carbon credits from wind energy are cheaper than forest carbon credits. Hammami et al. (2018) have investigated the tourist's behavior towards local Cretan food. The authors have implemented an empirical study using questionnaires aimed at international tourists in the airport of Chania, Crete regarding their perception of Cretan food tasted during their stay in the island. Their results indicated that tourists were satisfied with local gastronomy, increasing their intention to revisit Crete in the near future.

The aims of the current research are:

a) *To investigate the possibilities of lowering and zeroing the carbon footprint due to incoming international tourism in Crete with various technological and non-technological options including mitigation and offsetting schemes,*
b) *To estimate the cost of offsetting all incoming international tourism-related carbon emissions in Crete using carbon compensation credits, and*
c) *To estimate the carbon intensity of the tourism industry in Crete.*

3. Methodology

The research was carried out in the following steps. Firstly the factors affecting tourism related CO_2 emissions in Crete were identified and the possibilities of mitigating them with various technological and non-technological measures were analyzed. Secondly the possibility of offsetting these carbon emissions either with compensation credits or with creation of tree plantations acting as carbon sinks was investigated. Thirdly calculations regarding the cost of mitigation and zeroing tourism related CO_2 emissions in Crete as well as estimation of the carbon intensity of the tourism industry in the island were implemented. Data from existing research and studies in Greece and worldwide were used. Finally the findings of the current work are compared with the results of similar studies in other global tourism destinations.

4. Mitigation and Offsetting of Tourism-Related Carbon Emissions in Crete

Tourism-related carbon emissions in Crete, Greece can be mitigated or totally eliminated by various technological and non-technological measures. These include the use of less polluting fuels in air, sea and road transportation, increase of energy efficiency, replacement of fossil fuels use with renewable energies in tourist accommodation and use of more environmentally-friendly tourist activities in the island, and additionally by promoting carbon sequestration by tree plantations and using carbon compensation credits. Combination of the above-mentioned measures could result either in the mitigation or in the total elimination of carbon emissions related to international tourism in Crete.

5. Mitigation of Carbon Emissions Due to Transportation to the Destination

Air and sea transport of tourists to Crete is related with the consumption of fossil fuels resulting in carbon emissions. Most of the tourists arriving in the island and returning back use airplanes, since they arrive from long distances, and only a minority of them use ships. Current technology regarding fuels used in airplanes and ships does not allow the use of low or zero-carbon emission fuels. Future technology advances regarding the use of low or zero-carbon fuels and very efficient engines in commercial applications are not foreseen soon. Current studies regarding the overall carbon footprint of tourism in various islands indicated that air transport to the destination including tourists' return has the highest carbon impact. Therefore mitigation of carbon footprints due to air transport of tourists in Crete is not easy compared with its reduction in other tourism sectors. Additionally,

travelers, except a small minority, are not willing voluntarily to offset their carbon emissions due to air travel.

6. Mitigation of Carbon Emissions Due to Accommodation

Mitigation of carbon emissions in tourist accommodation can be achieved by replacing fossil fuels use with renewable energies. Various high efficiency energy technologies as well as renewable energy technologies are currently mature, reliable, cost-effective and broadly used in many applications. They include solar thermal energy for heat production, solar photovoltaic energy for electricity generation, high efficiency and geothermal heat pumps for space heating and cooling, solid biomass for heat production etc. Tourists use a lot of hot water during their summer vacations in Crete and it can be easily produced with simple solar thermal systems. The required technology is mature, well-known, cost-effective and used broadly in Crete during the last 30 years. Although fossil fuels including electricity generated by fossil fuels dominate in energy consumption in tourist accommodation, various hotels have started to use renewable energy technologies since they are profitable and more attractive to environmentally-conscious tourists. Additionally, the Greek government is offering various incentives, including financial subsidies and tax reliefs, in these enterprises in order to promote the higher use of locally available and environmentally friendly benign energy sources. Low/zero-carbon energy technologies which could be used in tourist accommodation in Crete decreasing their carbon emissions include:

a) Solar thermal systems for hot water production,

b) Solar photovoltaic systems for electricity generation,

c) High efficiency heat pumps including ground-source heat pumps for heat and cooling generation,

d) Locally produced solid biomass for heat generation, and

e) Various energy-saving technologies including low-energy lighting bulbs, BEMs, well-insulated doors, windows, facades, roofs etc.

7. Mitigation of Carbon Emissions Due to Food Consumption

Tourists consume food and drinks during their stay in Crete. Some of the ingredients are produced in the island while others are transported from their production sites. Transportation of food from long distances via ships and airplanes results in carbon emissions. The Mediterranean and Cretan diet is famous all over the world for its healthy impacts on humans. However, due to cost reasons, many hotels and restaurants serve meals which are based on imported ingredients due to the fact that some of them are cheaper. Others promote the Cretan diet based on locally produced materials targeting tourists willing to taste the local gastronomy. It has been proposed that in the future agricultural production in Crete should be focused in covering, apart from the needs of the local inhabitants, the needs of the approximately 5 mil. tourists visiting the island annually. This could offer economic and environmental benefits in Crete and it would also offer added value in tourism through the promotion of the tasty and healthy local gastronomy based on the Cretan diet. Reduction of transported food ingredients used in feeding tourists in Crete would result in the decrease of carbon emissions due to their transportation.

8. Mitigation of Carbon Emissions Due to Transportation on the Island

During their stay in Crete tourists visit various museums, cultural sites, antiquities and places of natural beauty including remote and unique beaches for swimming. In exploring the island, they use either public transportation or rented cars and motorbikes. Buses and cars in Crete have internal combustion engines using fossil fuels and the presence of electrified vehicles is rare while commercial battery-charging stations for electric cars do not exist today. Use of bio-fuels including bio-ethanol and biodiesel in vehicles is also limited. Therefore, road transportation in Crete is related with the use of fossil fuels, resulting in carbon emissions, while the increased use of vehicles with alternative fuels having low or zero-carbon emissions is not foreseen in the near future. Reduction of carbon emissions in transportation can be achieved in the future in Crete in the following ways:

a) Use of conventional vehicles with higher fuel efficiency,

b) Use of electric vehicles using renewable electricity for recharging their batteries,

c) Use of vehicles with internal combustion engines fuelled with bio-fuels,

d) Use of car sharing and car pooling in their transportation,

e) Use of bicycles and walking, and

f) Use of public transportation, particularly buses, instead of rented cars.

Methods of mitigating carbon emissions due to international tourism in Crete are presented in Table 1.

Table 1. Methods for mitigating CO_2 emissions in tourism industry in Crete, Greece

Sector	Method
Air flights to the destination including return journey	- Use of high-efficiency fuels combined with the use of more efficient engines
Sea transport to Crete	- Use of high efficiency fuels combined with the use of more efficient engines
Tourist accommodation	- Use of energy-saving techniques and technologies - Use of renewable energy technologies for heat, cooling and electricity generation
Various tourist activities in Crete including catering	- Preference of the local gastronomy with the use of locally produced food instead of imported - Preference of low-carbon emission transport modes including public transportation, walking, cycling, car sharing, electrified vehicles, high efficiency vehicles and vehicles fuelled by bio-fuels.

9. Offsetting Carbon Emissions with Carbon Compensation Credits

The clean development mechanism, defined in Kyoto's protocol, allows the implementation of a carbon emissions reduction project in developing countries which results in certified emissions reduction. Such projects can include installation of solar-PV systems in remote communities, creation of wind farms, replacement of old boilers with new ones which are more energy-efficient, or reforestation projects. Mitigation or total elimination of carbon emissions due to international tourism in Crete could be achieved with the engagement in such carbon reduction projects according to the clean development mechanism. It has been calculated that currently carbon offsetting costs 9€ per tCO_2. Total CO_2 emissions in Crete due to international tourism have been currently estimated at 2280.62 $ktCO_2$ or, excluding incoming and return tourist transportation, at 440.39 $ktCO_2$ (Vourdoubas, 2019). Therefore, annual offsetting of tourism-related CO_2 emissions in Crete would cost €20,525,580 while offsetting CO_2 emissions, excluding incoming and return tourist transportation, would cost € 3,963,510.

10. Offsetting Carbon Emissions with the Creation of Tree Plantations

Carbon dioxide emissions due to international tourism in Crete could be offset with the creation of tree plantations which absorb carbon through photosynthesis acting as atmospheric CO_2 sinks. Available data regarding carbon sequestration from tree plantations vary and it will be assumed that fast-growing forest trees could remove annually 20 tCO_2 per ha. Forest restoration either in Crete or elsewhere could remove part or all of carbon emissions due to tourism in Crete. Assuming total annual CO_2 emissions in Crete, including incoming and return air transportation, at 2280.62 $ktCO_2$, the required forest area which could absorb this quantity is estimated at 114 031 ha. Annual emissions without air transportation of tourists have been estimated at 440.39 $ktCO_2$ and the required forest area for its removal is estimated at 22 019 ha. The size of the required forest areas estimated is large compared with the size of the island and it is neither realistic nor feasible to offset tourism-related carbon emissions with reforestation projects in Crete. The cost of offsetting annual CO_2 emissions due to international tourism in Crete is presented in Table 2.

Table 2. Cost of offsetting annual CO_2 emissions due to international tourism in Crete with forest carbon credits

	Emissions including incoming and returning tourists' transportation	Emissions excluding incoming and returning tourists' transportation
Annual CO_2 emissions [1]	2280.62 $ktCO_2$	440.39 $ktCO_2$
Area of forest plantations for offsetting all carbon emissions	114 031 ha	22 019 ha
Annual cost of offsetting all carbon emissions with forest carbon credits [2]	€ 20 525 580	€ 3 963 510

[1] Vourdoubas, 2019;

[2] Cost of forest carbon credits = 9 € per tCO_2.

11. Estimation of the Carbon Intensity of the Tourism Industry in Crete

The carbon intensity of the tourism industry in Crete has been calculated as the quotient of its total carbon emissions and the gross domestic product of the island attributed to tourism. Gross domestic product per capita in Crete in 2015 was calculated at 13,912€ (www.statistics.gr), while the population in the island was 621,340

inhabitants (Census, 2011, www.statistics.gr). The share of tourism to the gross domestic product in Crete has been estimated at 47% (Angelakis, 2018). The gross domestic product of Crete in 2015 was estimated at 8.64 bil.€ while the amount attributed to the tourism industry was at 4.06 bil.€. Taking into account that CO_2 emissions in Crete due to international tourism are at 2280.62 $ktCO_2$ (including all the emissions due to air and sea transport), or excluding incoming and return tourist transportation, at 440.39 $ktCO_2$ (Vourdoubas, 2019), the carbon intensity of the tourism industry in Crete is estimated at 0.562 $kgCO_2$/€, or excluding incoming and return tourist transportation, at 0.108 $kgCO_2$/€. Various parameters related with the mitigation and compensation of tourism-related carbon emissions in Crete are presented in Table 3.

Table 3. Parameters related with mitigation and compensation of tourism -related carbon emissions in Crete

Parameter	Value
[1] Tourism -related annual CO_2 emissions in Crete (including air and sea transport)	2280.64 $ktCO_2$
[1] Tourism -related annual CO_2 emissions in Crete (excluding air and sea transport)	440.39 $ktCO_2$
Annual cost of total elimination of CO_2 emissions in Crete (including air and sea transport)	20 525 580 €
Annual cost of total elimination of CO_2 emissions in Crete (excluding air and sea transport)	3 963 510 €
Area of forest plantations for offsetting all annual carbon emissions (including air and sea transport)	114 031 ha
Area of forest plantations for offsetting all annual carbon emissions (excluding air and sea transport)	22 019 ha
Gross annual regional domestic product in Crete attributed to tourism	4.06 bil. €
Annual cost of the total elimination of CO_2 emissions in Crete (including air and sea transport) to gross annual regional domestic product in Crete attributed to tourism	0.51%
Carbon intensity of the tourism industry in Crete (including air and sea transport)	0.562 $KgCO_2$/€
Carbon intensity of the tourism industry in Crete (excluding air and sea transport)	0.108 $KgCO_2$/€

[1] Vourdoubas, 2019.

12. Discussion

Since the highest share of CO_2 emissions into the atmosphere attributed to the tourism industry in Crete is due to air travel, many published reports have emphasized the necessity to restrict air transportation during the holidays. However this is impossible for tourists arriving from long destinations to Crete while international tourism in the island is increasingly dependent on aviation. Mitigation of CO_2 emissions in aviation is not easy with the existing technology while mixed mitigation schemes could be developed, financed by tourists, air travel companies, hotels and public authorities. Decrease of CO_2 emissions in tourist accommodation with the use of existing technology is easier than in transportation while the required technology is currently mature, reliable and cost-effective. Tourist accommodation is a sector where significant reduction in GHGs can be achieved. Decrease of carbon emissions due to food consumption can be achieved if locally produced food ingredients in Crete are used in the preparation of tourist meals, minimizing the use of imported food. This can be combined with the promotion of the local gastronomy and the healthy Cretan diet. Reduction of carbon emissions caused during transportation of tourists to the island can be achieved with the use of less polluting modes of transport. Taking into account the global efforts to cope with climate change, the island of Crete could be transformed in the future into a carbon-neutral tourist destination with the combined use of low-carbon technologies in various tourism activities and by offsetting the remaining carbon emissions with carbon credits. This will offer a competitive advantage in the island and it will attract more environmentally conscious tourists who usually spend more during their holidays. Estimated carbon intensities of the tourism industry in Crete at 0.562 $kgCO_2$/€ are in the same range of tourism-related carbon intensities reported in other EU countries at 0.44-0.85 $kgCO_2$/€ (Perch-Nielsen et al., 2010).

13. Conclusions

Mitigation and compensation of GHG emissions due to the tourism industry in Crete can be achieved with various technological and non-technological measures. Air transport to Crete and return journeys have the highest share in total CO_2 emissions, due to the bunker fuels used, followed by carbon emissions in accommodation. Carbon emissions in hotels and in other types of accommodation can be easily reduced while mitigation of CO_2 emissions due to air flights is rather difficult due to the lack of appropriate technologies and low carbon fuels. Offsetting of carbon emissions can also be achieved with the use of carbon compensation credits or with the implementation of afforestation projects. The total annual cost of eliminating all carbon emissions due to the tourism industry in Crete has been estimated at 20,525,580€ (including all carbon emissions due to air and sea transport) and at 3,963,510€ (excluding all carbon emissions due to air and sea transport). The

amount of 20,525,580€ corresponds to 0.51% of the total annual income of the tourism industry in Crete, estimated at 4.06 bil.€. The required area of forest plantations for offsetting all carbon emissions has been calculated at 114,031 ha. The carbon intensity of the tourism industry in Crete is estimated at 0.562 $kgCO_2/€$ including emissions due to air and sea transport, or excluding incoming and return tourist transportation, at 0.108 $kgCO_2/€$. Further research should be focused on the comparison of the carbon intensity of the tourism industry in Crete with the carbon intensity of other industries in Greece and abroad. Additionally, empirical studies regarding the attitude of international tourists arriving to Crete for voluntary compensation of their carbon emissions resulting during their vacations will reveal the appropriate policies for mitigation of tourist-related CO_2 emissions in the island.

References

Angelakis, G. (2018). *Tourism observatory: A joint effort for an innovative entrepreneurship in Western Crete.* Retrieved at 8/7/2019 from http://chania-cci.gr/wp-content/uploads/2017/10/angelakis.pdf

Becken, S. (2004). How tourists and tourism experts perceive climate change and carbon offsetting schemes. *Journal of Sustainable Tourism, 12*(4), 332-345. https://doi.org/10.1080/09669580408667241

Becken, S. (2005). Harmonizing climate change adaptation and mitigation: the case of tourist resorts in Fiji. *Global Environmental Change, 15*(4), 381-393. https://doi.org/10.1016/j.gloenvcha.2005.08.001

Becken, S. (2013). A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives, 6*, 53-62. https://doi.org/10.1016/j.tmp.2012.11.006

Bernal, B., Murray, L. T., & Pearson, R. H. (2018). Global carbon dioxide removal rates from forest landscape restoration activities. *Carbon Balance and Management, 13*, 22. https://doi.org/10.1186/s13021-018-0110-8

Carbon neutral tourist, A guide to reduce your carbon footprint. (2012). CARBONTOUR, LIFE09 ENV/GR/000297. Retrieved from http://carbontour.uest.gr/uploads/DELIVERABLE_5.2b_GUIDE_FOR_TOURISTS_EN.pdf

Dodds, R., Leung, M. L., & Smith, W. (2008). Assessing Awareness of Carbon Offsetting by Travelers and Travel Agents. *Anatolia, 19*(1), 135-148. https://doi.org/10.1080/13032917.2008.9687058

Dubois, G., Peeters, P., Ceron, J. P., & Gossling, S. (2011). The future tourism mobility of a world population: Emission growth versus climate policy. *Transportation Research Part A, 45*, 1031-1042. https://doi.org/10.1016/j.tra.2009.11.004

Eijgelaar, E. (2011). Voluntary carbon offsets a solution for reducing carbon emissions? Assessment of communication aspects and mitigation potential. *European Journal of Transport and Infrastructure Research, 11*(3), 281-296.

Gössling, S. (2009). Carbon neutral destinations: A conceptual analysis. *Journal of Sustainable Tourism, 17*(1), 17-37. https://doi.org/10.1080/09669580802276018

Gössling, S., & Schumacher, K. (2010). Implementing carbon neutral destination policies: Issues from the Seychelles. *Journal of Sustainable Tourism, 18*(3), 377-391. https://doi.org/10.1080/09669580903147944

Gössling, S., Broderick, J., Upham, P., Ceron, J. P., Dubois, G., Peeters, P., & Strasdas, W. (2007). Voluntary carbon offsetting schemes for aviation: Efficiency, Credibility and Sustainable Tourism. *Journal of Sustainable Tourism, 15(3),* 223-248. https://doi.org/10.2167/jost758.0

Gössling, S., Hall, M. C., Peeters, P., & Scott, D. (2010). The future of tourism: Can tourist growth and climate policy be reconciled? A mitigation perspective. *Tourism Recreation Research, 35*(*2),* 119-130. https://doi.org/10.1080/02508281.2010.11081628

Gössling, S., Hultman, J., Haglund, L, Källgren, H., & Revahl, M. (2009). Voluntary carbon offsetting by Swedish Air Travellers: Towards the Co-creation of Environmental Value? *Current Issues in Tourism, 12*(1), 1-19. https://doi.org/10.1080/13683500802220687

Gössling, S., Scott, D., & Hall, C. M. (2015). Inter-market variability in CO_2 emission-intensities in tourism: Implications for destination marketing and carbon management. *Tourism Management, 46*, 203-212. https://doi.org/10.1016/j.tourman.2014.06.021

Hammami, A. M., Stanton, J. L., Drakos, P., Baourakis, G., Dijk, G. Van, & Mamalis, S. (2018). Tourist's Behavior Towards Local Cretan Food. In K. Mattas, G. Baourakis, & C. Zopounidis (Eds.), *Sustainable Agriculture and Food Security: Aspects of Euro-Mediterranean* (Business Cooperation, series: Cooperative Management, 49-61). Springer, Switzerland. https://doi.org/10.1007/978-3-319-77122-9_4

Hares, A., Dickinson, J., & Wilkes, K. (2010). Climate change and the air travel decisions of UK tourists. *Journal of Transport Geography, 18*, 466-473. https://doi.org/10.1016/j.jtrangeo.2009.06.018

Higham, J., Cohen, S. A., Cavaliere, C., Reis, A., & Finkler, W. (2015). Climate change, tourist air travel and radical emissions reduction. *Journal of Cleaner Production, 111 (Part B),* 336-347. https://doi.org/10.1016/j.jclepro.2014.10.100

Huang, C., & Deng, H. (2011). The model of developing low carbon tourism in the context of leisure economy. *Energy Procedia, 5*, 1974-1978. https://doi.org/10.1016/j.egypro.2011.03.339

Juvan, E. & Dolnicar, S. (2014). Can tourists easily choose a low carbon footprint vacation? *Journal of Sustainable Tourism, 22*(2), 175-194. https://doi.org/10.1080/09669582.2013.826230

Mair, J. (2011). Exploring air traveler's voluntary carbon-offsetting behavior. *Journal of Sustainable Tourism, 19*(2), 215-230. https://doi.org/10.1080/09669582.2010.517317

McKercher, B., Prideaux, B., Cheung, C., & Law, R. (2010). Achieving voluntary reductions in the carbon footprint of tourism and climate change. *Journal of Sustainable Tourism, 18*(3), 297-317. https://doi.org/10.1080/09669580903395022

Perch-Nielsen, S., Sesartic, A., & Stucki, M. (2010). The greenhouse gas intensity of the tourism sector: The case of Switzerland. *Environmental Science and Policy, 13*, 131-140. https://doi.org/10.1016/j.envsci.2009.12.002

Smith, I. J., & Rodger, C. J. (2009). Carbon emission offsets for aviation-generated emissions due to international travel to and from New Zealand. *Energy Policy, 37*(9), 3438-3447. https://doi.org/10.1016/j.enpol.2008.10.046

Toochi, E. Ch. (2018). Carbon sequestration: How much can forestry sequester CO_2? *Forestry Research and Engineering: International Journal, 2*(3), 148-150. https://doi.org/10.15406/freij.2018.02.00040

Using forest carbon credits to offset emissions in the downstream business, Concawe report No 9/17, 2017. Retrieved from https://www.concawe.eu/wp-content/uploads/2017/09/Rpt_17-9.pdf

Velonaki, A., & Stone, Ch. (2015). *Carbon offsetting schemes-responsible tourism behavior: Issues & challenges in the 21st century.* conference Euro CHRIE at Manchester, UK, October 2015.

Vourdoubas, J. (2018). Hotels with net zero carbon emissions in the Mediterranean region: Are they feasible? *Journal of Tourism and Hospitality Management, 6*(2), 72-79. https://doi.org/10.15640/jthm.v6n2a6

Vourdoubas, J. (2019). Estimation of carbon emissions due to tourism in the island of Crete, Greece. *Journal of Tourism and Hospitality Management, 7*(2). Retrieved from http://www.statistics.gr

Yang, W. (2010). The development of tourism in the low carbon economy. *International Business Research, 3*(4), 212-215. https://doi.org/10.5539/ibr.v3n4p212

Zeppel, H. (2012). Collaborative governance for low carbon tourism: Climate change initiatives by Australian tourism agencies. *Current Issues in Tourism, 15*(7), 603-626. https://doi.org/10.1080/13683500.2011.615913

Zeppel, H., & Beaumont, N. (2013). Assessing motivations for carbon offsetting by environmentally certified tourism enterprises. *Anatolia, 24*(3), 297-318. https://doi.org/10.1080/13032917.2012.759982

Zhang, J., & Zhang, Y. (2018). Carbon tax, tourism CO_2 emissions and economic welfare. *Annals of Tourism Research, 69*, 18-30. https://doi.org/10.1016/j.annals.2017.12.009