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An International Comparative Analysis of Approaches to Measure the Carbon Footprint of Tourism

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Abstract

Tourism contributes significantly to climate change. However, it has continuously been excluded from national emission frameworks globally. Climate action must play a leading role in national tourism plans by measuring, monitoring and reporting tourism emissions for sustainable destination management. The purpose of this study is to identify the most applicable approach to measure the carbon footprint of tourism internationally. This study conducted a comparative analysis of the international approaches and toolkits available to measure tourism emissions. Consequently, contributes new knowledge to tourism policymakers by outlining the advantages, limitations and barriers of utilizing each approach. The findings identified that the most favorable approaches cannot be used internationally due to tourism data limitations. Thus, barriers to establishing and maintaining a standardized measurement and system to accurately monitor the level of tourism decarbonization worldwide are created. Nevertheless, tourism policymakers can begin to minimize these barriers by collecting credible data to establish the Tourism Satellite Accounts. Climate change is a significant crisis facing humanity, and until now, this research has not been completed.

Keywords: Climate Action; Tourism Emissions; Sustainable Destination Management; Carbon Footprint Methodology; Decarbonization

Abbreviations: EU: European Union; SMEs: Small-Medium-Enterprises; SDGs: Sustainable Development Goals; LCA: Life Cycle Analysis; EE-IO-LCA: Environmentally Extended Input-Output Analysis - Life Cycle Analysis

Introduction

Climate change and tourism have a bi-directional relationship. Climate is an important element in a destination's tourism product and any change in climate attributes may threaten a destination's competitiveness, sustainability, and economic viability [1]. Tourism is highly climate-sensitive; however, it is a significant contributor to climate change. Between 2009 - 2013, tourism's global carbon footprint was estimated to be 4.5 $GtCO_2eq$, nearly 8% of global emissions [2]. As stated by Scott [3,4], Loehr & Becken [5] and Zha et al. [6], the leading climate change challenge that the tourism industry is faced with is the excessive levels of decarbonization required to transition towards Net-Zero emissions before 2050. Although low-carbon tourism is proposed as an alternative tourism type to reduce emissions and aid the Net-Zero transition, there is strong evidence that showcases that tourism is not on track to reach Net-Zero [7,8]. Additionally, continued growth in the industry, at expected rates, represents an overwhelming barrier to achieving Net-Zero. Hence, contradicting tourism's narrative of progressively and successfully engaging with climate action and on the sustainability pathway.

Tourism cannot be considered sustainable unless it is successfully decarbonizing. Tourism destinations that advocate sustainability but provide no evidence of decarbonization are vulnerable to the accusations of greenwashing [3,4]. The lack of measuring and reporting tourism emissions remains a crucial barrier to identifying the progression towards a Net-Zero. In 2022, the European Union (EU) established a new 'Corporate Sustainability Reporting Directive', which requires large organizations to measure and report their environmental, social and economic impacts by 2024 and Small-Medium-Enterprises (SMEs) by 2028. This directive will help investors, civil society organizations, consumers and other enterprises to evaluate an organization's sustainability performance [9]. Additionally, in

March 2023, the EU adopted a proposal for a Directive on 'Green Claims' to further empower consumers in the green transition. This directive aims to act against greenwashing and make green claims reliable, comparable and verifiable across the EU [10]. Hence, assessing the carbon footprint of tourism is essential to identify high-intensive emission sources and develop evidence-based decarbonization strategies to increase sustainability performance [11,12]. Furthermore, the data empowers policymakers to compare tourism emissions internationally, be transparent with reporting the environmental impact of tourism operations to support green claims and remain competitive. Once the carbon footprint of tourism is identified and understood, only then can appropriate and location-specific decarbonization policies and strategies be implemented.

Within the literature, several analytical approaches, calculators and toolkits have been utilized to measure the carbon footprint of tourism at a national and regional level [13,14]. Additionally, the United Nations global leaders, many destinations national tourism bodies and governments, and credible third-party businesses have developed user-friendly carbon footprint calculators and toolkits [15]. Hence, encouraging individuals, enterprises and tourism bodies to take accountability and responsibility for their environmental impact by measuring and reporting their carbon footprint. However, there is still a lack of a consistent and standardized approach and system boundaries to measure emissions [12,14,16]. Consequently, the purpose of this study is to identify the most applicable approach to measure the carbon footprint of tourism internationally. The objective of this study was to establish a framework to conduct a comparative analysis of the international approaches and toolkits available to measure tourism emissions at an individual, business and national or regional level. Thus, informing tourism policymakers, planners, stakeholders and academics on the advantages, limitations and barriers of utilizing each approach. This information is essential to ensure that policymakers and planners can reduce the limitations and barriers of implementing a standardized approach. To ensure tourism emissions are accurate and comparable globally.

Literature review

Climate change affects tourism destinations differently, and some of the most vulnerable are the least developed countries and SIDS destinations [17,18]. The warming climate in northern Europe will likely benefit these destinations, making outdoor activities more appealing. However, countries in Africa that are already hot and arid will most likely be negatively affected by the warming climate [19,20]. Despite these threats, destinations continue to develop exposed locations and invest in emission-intensive technologies and market segments [5,17]. Therefore, it is essential that tourism policymakers and planners measure and report tourism emissions regularly to develop location-specific and evidence-based decarbonization policies and strategies - as it is not a case of one solution that fits all. Hence, these efforts will contribute towards sustainable tourism development and management.

Sustainable tourism governance

In terms of destination planning and development, it has long been recognized that tourism needs to embrace sustainability to combat climate change. The UNWTO [15] has continuously highlighted the importance of managing and reporting tourism emissions as a central role of climate action. For instance, the United Nations Sustainable Development Goals (SDGs) 12 and 13 are a worldwide agreement focused on mitigating climate change and increasing sustainability through decarbonization policies and strategies [21,22]. Furthermore, the One Planet Sustainable Tourism Program aims to accelerate sustainable tourism policies and practices to address the challenges of pollution, biodiversity loss and climate change. In addition, the Glasgow Declaration on Climate Action in Tourism catalyzes the urgency of the need to accelerate climate action in tourism [15,23]. This declaration secures strong actions and commitments to support the global goals of halving emissions over the next decade and reaching Net-Zero emissions before 2050. However, very few destinations have become signatories, it is mainly tourism stakeholders. Therefore, a legal remit to measure, monitor, report and act on tourism decarbonization may be necessary to ensure tourism at a global level transition towards a Net-Zero industry before 2050. For example, the EU has led the way by introducing the new Corporate Sustainability Reporting Directive [9]. Other political leaders may consider following these steps towards sustainability.

Tourism cannot be considered sustainable unless it is actively decarbonizing. Lenzen et al. [2] identified that tourism's global carbon footprint was 4.5 $GtCO_2eq$ (2009-2013), accounting for nearly 8% of global emissions. Evidently, tourism contributes significantly to global emissions. To date, national tourism plans lack serious discussion and planning for tourism decarbonization globally [3,4,13]. Crucially, baseline data for the carbon footprint of tourism at a national level are scarce or non-existent and few tourism organizations are measuring and monitoring emissions [15,24]. As a result, tourism policymakers, planners and stakeholders cannot monitor and manage the level of decarbonization in tourism. Consequently, the tourism industry is left vulnerable to climate change impacts and accusations of greenwashing sustainability. Importantly, tourism committed itself to becoming Net-Zero before 2050 but is not on track to reach this target. Despite the narrative of pursuing a sustainable tourism development pathway [8,13,24]. Again, the EU has proposed to implement a new directive aimed at combating greenwashing and making green claims reliable [10]. Therefore, tourism policymakers, planners, businesses and academics must collaborate to encourage more alignment, transparency and continuity in emission monitoring to support well-informed decision-making and avoid greenwashing.

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Carbon footprint of tourism

Carbon footprint is an accounting assessment tool that identifies, monitors, manages and eliminates or reduces areas of high emissions [11,25]. A weighted number is placed on the environmental impact of human activities. Activity data is collected and converted into emission levels. According to Dwyer & Spurr [25], tourism carbon footprints can be assessed at many levels, such as an individual organization, product or service, regionally, nationally and globally. There are two units of measurement for the assessment: CO_2 (only carbon) or CO_2eq (the six most malicious greenhouse gases known as carbon equivalent) [13]. According to many academics, it is recommended to measure the direct and indirect emissions of scope 1, 2 and 3 (Table 1) in the unit measurement of carbon equivalent (CO_2eq) to maintain a standardised measurement (Cadarso et al., 2016) [13,16]. However, there is a common challenge in measuring and reporting Scope 3 emissions across all industries [24]. This is due to the fragmented regulatory landscape and lack of government support, insufficient internal and external budgets for a Net-Zero transition as well as dependency on infrastructure.

Table 1: Green House Gas (GHG) Protocol Emissions Categorisation.

Scope 1: (direct emissions from operations)
• Fuel combustion
• Operation of vehicles and fugitive emissions
Scope 2: (indirect emissions from purchased energy)
• Generation of purchased electricity, heating or cooling and steam
Scope 3: (indirect emissions in the value chain)
• Purchased goods and services
• Business travel
• Employee commuting
• Waste disposal
• Transportation up and downstream
• Investments
• Leased assets
• Franchise activities

Source: [24].

From comparing previous international studies, that assessed the carbon footprint of tourism [13,16], it is evident that there is not a standardized approach to monitoring tourism emissions. These studies are not directly comparable due to the lack of uniformity and consistent Scope of impact measured, the timeframe of measurement, and the units of measurement. Thus, yielding an inconsistent basis for comparison of the carbon footprints of tourism destinations on a global scale. According to the UNWTO [15], existing approaches and toolkits often do not cater for the needs of tourism organizations, especially SMEs, as few are freely accessible and designed for wide use. Furthermore, some third-party businesses that offer free tools to measure emissions typically have an overall purpose of trying to sell offsetting programs to compensate for the emissions produced. While other consultants and certification companies that charge for the utilization of its measurement tool will typically deliver deeper support. Regardless, according to Conefrey & Hanrahan [13,26], it is claimed that the more comprehensive approaches to measuring emissions, such as the bottom-up and top-down approaches, are more accurate at measuring tourism emissions but require more resources, and detailed data which can be time-consuming. Considering the above literature, it is necessary to establish a framework to conduct a comparative analysis to identify the most applicable approach to measure, monitor and report the carbon footprint of tourism internationally. As a result, contributing new knowledge by highlighting the advantages, limitations and barriers of utilizing each approach. Hence, showcasing the importance of minimizing limitations and barriers so tourism policymakers, planners, and stakeholders can utilize a standardized approach to measure and monitor tourism emissions.

Methodology

Awareness of the carbon footprint of tourism is crucial for the transition towards a Net-Zero industry before 2050 [15]. Hence, the impetus for this study was to identify the most applicable approach to measuring the carbon footprint of tourism internationally. To this paper, a comparative analysis of the approaches was conducted to outline the advantages, limitations and barriers of utilizing each approach. A comparative analysis is used to understand a complex phenomenon by identifying commonalities across cases [27-30). The comparative analysis employed in this study is a mixed-methods approach as it combines aspects of both quantitative and qualitative approaches.

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To fully exploit the benefits of comparative analysis, the analysis is typically based on a common theoretical framework to facilitate constant comparison throughout the research process.

Method

The authors conducted desk-based research, by gathering and comparing data from previous research that assessed the carbon footprint of tourism at a regional and national level [13,14,16,26]. Additionally, globally recognized tools from global leaders, national tourism bodies and credible consultant businesses were included in the analysis (Table 2). Furthermore, the researchers of this study collaborated with previous researchers who assessed the carbon footprint of tourism and gained access to the complete data sets. Data from educational institutes and open-source data were utilized to ensure that no relevant data were excluded. Therefore, a theoretical framework was constructed to facilitate the comparative analysis of these approaches (Table 3). The sixty-eight criteria analyzed are broken down into four main categories. The criteria used to explore these approaches were developed from an in-depth theoretical analysis of previous academic research and principle guiding documents [13,15,44,45]. As a result, the criteria provide a framework for constant comparison of the approaches used to assess the carbon footprint of tourism, thus, biased opinions are reduced. To secure a valid sample, the researcher carefully considered the sampling and selection procedures for this study.

Table 2: Calculators, toolkits and approaches analyzed.

Third-party calculators & toolkits
Carbon Footprint Ltd. (Environmental Protection Agency recommended calculator)
Hotel Footprinting Tool
Wayaj (IMPPACTTM Program)
Sustainable Travel International (carbon calculator)
EarthCheck (carbon calculator)
Hotel Carbon Measurement Initiative
Weeva (Tool)
SME Climate Hub (calculator)
CARMACAL (carbon calculator)
National, international & supranational calculators, toolkits & approaches
European Tourism Indicator System
CO_2RISM calculator (Norway)
Climate Toolkit 4 Business (Fáilte Ireland)
Calculate CO_2 (UNDP Montenegro)
CO_2 calculator (VisitFinland)
CO_2 calculator (Spain)
CO_2 calculator (Málaga Costa Del Sol)
CO_2 Calculator (Indonesia)
Destination Carbon Footprint Tool (Smart Assessment Sustainable Tourist Destinations)
Desti MED (Ecotourism Footprint Calculator- EU)
DEFRA GHG (UK Department for Environment, Food & Rural Affairs Greenhouse Gases Conversion Factors)
Bottom-up/ Life Cycle Analysis (LCA)
Environmentally Extended Input-Output Analysis (EE-IO) (Top down)
Environmentally Extended Input-Output Analysis – Life Cycle Analysis (LCA) (Hybrid)
UK Department for Environment, Food & Rural Affairs Greenhouse Gases Conversion Factors - Life Cycle Analysis (DEFRA- LCA) (Hybrid)
UNFCCC emissions calculator (United Nations Framework Convention on Climate Change Greenhouse Gas emissions calculator)

Source: [13,15].

Table 3: Summary of the criteria analysed to determine similarities and differences between approaches.

Criteria	Sub-category criteria
	-Aviation/ transportation
	-Accommodation
	-Building energy use, food and beverages, and offsetting programs

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	-Food/ drink
	-Tourism attractions/ activities
	-Assess emissions of all products and services consumed
	-All products/ delivery chain emissions traced through the economic-environmental accounts
	-Expenditure on products/ services
	-'Cradle to the Grave' concept
	-Captures emissions from Scopes 1, 2 and 3
	-Identifies & prioritises sustainability issues and suggests actions
	-Free for individuals/ micro-businesses only, compares your carbon footprint with the average person in your country
	-Flexible system adapted to the needs of users and easy to compare results internationally
	-Free access, user friendly, can be adjusted and 'ready to employ'
	-Videos/ guides on how to work the calculator
	-Estimates emissions associated with the supply chain/ differentiates diet type emissions
	-Includes emissions from distance uplift/ radiative forcing
	-Differentiates between tourist markets, and identifies tourists travelling together
	-Environmental Protection Agency recommended, considers emissions by the type of flight, and seat class, and assumes an average plane occupancy
	-Regularly updates data
	-Advises on reducing emissions/ offset projects
	-Won a United Nations World Tourism Organisation award, can enter specific itinerary details per day, and it will save data
	-Breakdown of total emissions into categories
	-Linked to Google Maps- easily finds the distance between places
	-Greater accuracy
	-Quantifies the linkages between tourism's economic contribution and the impact of emissions
	-Data is already collected through national tourism organisations and identifies consumption patterns by tourist segments or countries
	-Pinpoints emissions hot spots and predict changes if alternatives are chosen
	-Enables a national tourism carbon inventory to be compatible with the System of National Accounts
	-Can be implemented at single-region or multi-region
	-Integrates sustainability into macro-level policy framework and disseminates information on tourism, carbon emissions and social welfare
	-Comparable nationally because it is based on the Tourism Satellite Accounts
	-Measures the sectoral-level emissions within the Paris Agreement while linking it with the progress of Sustainable Development Goals
	-Internationally recognised tool
	-Contains detailed background information which explains the development of specific emission values
	-Improves the accuracy by replacing economic data with physical data to solve price heterogeneity and reduce estimation errors
	-More accurate and comprehensive
	-Reduces levels of uncertainty
	-Increases effective target campaigns
	-Most holistic method, as it is capable of estimating the direct and the maximum extent of indirect Green House Gas emissions from products and services
	-Highlights yearly performance indicators, benchmarking and comparison to regional averages
	-Showcases financial savings associated with reducing emissions

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	-Underestimates the carbon footprint
	-Overestimates the carbon footprint
	-Not explicitly made for tourism, time-consuming and accurate data is required
	-Emission inventories are not regularly updated
	-Not suitable for individual use
	-Life Cycle Analysis in the building sector is not rational, and variations in itineraries and purchasing patterns make it difficult to accurately complete
	-Inaccurate assumptions of maximum load factors and average occupancies from specific modes of transportation
	-Homogeneity: assumes that all businesses produce using the same standard of technology/ proportionally: implies that the impact will be doubled if consumption of one service is doubled. Does not consider price fluctuations or capacity utilisation ratios
	-Not able to breakdown energy consumption at business levels and reduces effective targeting of energy efficiency campaigns
	-Applications of this method in other countries should be made with caution
	-Do not consider potential end-use GHGs or land-use change impacts
	-Incomplete sectorial statistics and assumed linear relationships between sector outputs and environmental burdens
	-Unable to address the totality of the life cycle emissions and other indirect emissions from the value chain
	-Some uncertainty as assumptions has to be made for products and services. Precise calculations and results are difficult to truly establish
	-Limited emissions/impact categories
What are the barriers to implementing the approach?	-Lack of data, awareness and familiarity with the toolkit
	-Lack of resources
	-Requires interdisciplinary collaboration
	-Doubts on credibility
	-Financial pressure
	-Timer consuming
	-Challenges for macro-level data analyses, uncertainty and estimation errors increase when consumers' preferences are heterogeneous
	-Complex and unmanageable with large visitor volumes and a lack of transparency as restricted public access to the background data
	-Various styles of approach make comparisons difficult – no single standard developed yet
	-Tourism Satellites Accounts are not available in every country

Source adapted and modified: [13,15,31-43].

Sample and Selection

Given that this study aimed to identify the most applicable approach that can be utilized to assess the carbon footprint of tourism internationally. The research involved analyzing twenty-five approaches that have been previously used in academic studies and internationally, nationally and regionally recognized.

Data Analysis

The data generated from the twenty-five approaches was inputted into a comparative analysis tool for constant comparison throughout the research process. Thus, it highlights any similarities or differences between the selected approaches. This data analysis procedure allowed the researchers to use the comparative analysis tool (Table 3) to identify the most applicable approach to be implemented internationally.

Results and Discussion

The principal areas that emerged from within the analysis are discussed in the context of carbon footprint approaches. The comparative analysis aimed to identify the most applicable approach that can be utilized to measure the carbon footprint of tourism internationally. Tables 4-15 highlighted the many advantages, limitations and barriers to implementing the

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available approaches. Consequently, this information can enable policymakers and planners to minimize the limitations and barriers of implementing a standardized approach - to ensure tourism emissions are comparable globally. Hence, encouraging destinations to prepare for the decarbonization of tourism with evidence-based decision-making. Initial findings from the comparative analysis of the twenty-five approaches identified that only 40% of approaches measure emissions from all tourism products and services consumed (Tables 4-5). In comparison, 76% of approaches measure emissions from the consumption of accommodation and 88% for aviation and/or transportation emissions. Surprisingly, 84% of the approaches have low levels of tourism consumption components included in the measurement of emissions. Thus, underestimating emissions as the approaches does not target and measure all carbon-intensive tourism operations.

Table 4: Comparing the types of consumption assessed by the approaches available to measure emissions.

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustainable Travel International	Earth Check	Hotel Carbon Measurement Initiative	Weeva	SME Climate Hub	CARMACAL
Aviation and transportation			X	X	X		X	X	X
Accommodation	X	X			X	X	X	X	X
Building energy use, food and beverages, and offsetting programs	X								
Food & drink	X						X	X	
Tourism attraction/ activities	X				X			X	X
Assess emissions of all products and services consumed	X						X	X	
All products and delivery chain emissions traced through the economic- environmental accounts									
Expenditure on tourism products and services	X						X	X	
Life-cycle analysis (emissions from production to end-of-life)	X						X		
Captures Scope 1, 2 & 3 emissions							X	X	

Source adapted and modified: [13,15,31-43].

Table 5: Comparing the types of consumption assessed by the approaches available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches															
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO_2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Aviation and transportation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Accommodation			X	X	X	X			X	X	X	X	X	X	X	X
Building energy use, food and beverages, and offsetting programs																

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Food & drink					X					X		X	X	X	X	X
Tourism attraction/ activities					X				X	X			X	X	X	X
Assess emissions of all products and services consumed					X						X	X	X	X	X	X
All products and delivery chain emissions traced through the economic- environmental accounts					X							X		X	X	X
Expenditure on tourism products and services					X							X		X	X	X
Life-cycle analysis (emissions from production to end-of-life)													X	X	X	X
Captures Scope 1, 2 & 3 emissions					X						X	X		X	X	X

Source adapted and modified: [13,15,31-43].

In terms of the carbon calculators, the recommended Environmental Protection Agency carbon footprint calculator, Weeva and the SME Climate Hub calculators have medium levels of tourism components included. Together these findings highlight that not all carbon calculators are inaccurate. Consequently, these findings do not support the theory previously advocated by Filimonau [46] that all calculators measurements are inaccurate. This is possibly due to the continuous increase and development of carbon calculators. Nevertheless, the approaches with the highest level of tourism components included in the measurement are the more comprehensive and time-consuming approaches supporting the theory previously advocated by Sun (2021) and Conefrey & Hanrahan [13,14,26] such as the Environmentally Extended Input-Output Analysis (EE-IO), Environmentally Extended Input-Output Analysis - Life Cycle Analysis (EE-IO- LCA) (Hybrid) and UK DEFRA GHG conversion factors - Life Cycle Analysis (LCA) (Hybrid). The analysis identified that all twenty-five approaches have many advantages to measuring emissions (Tables 6-10). One prominent finding is that the majority (72%) of the approaches (Tables 6-10) are free to access, deemed user-friendly, adjustable to the needs of the user and ready to employ. Additionally, this study highlighted that 64% of the approaches give a breakdown of the emissions into different categories, which is beneficial to identify and prioritize the carbon-intensive sectors. Furthermore, 60% of the approaches regularly update their data for more accurate carbon footprint measurements. Compared to the top-down approach, which utilizes historical monetary data rather than tourists' actual behavior [47,48]. Therefore, this approach does not portray tourism's present-day environmental impact. Since the tourism industry has continuously grown throughout the years and tourists travel further and more frequently, this approach could potentially underestimate tourism emissions.

In terms of the third party carbon calculators and toolkits (Tables 6-7), 22% have medium levels of advantages to measuring emissions. For example, Earth Checks carbon calculator and Weeva. Compared to the national, international and supranational calculators, toolkits and approaches (Tables 8-9), 13% have medium levels of advantages to measuring emissions. For instance, the Environmentally Extended Input-Output Analysis – Life Cycle Analysis (Hybrid) and the UNCCC emissions calculator. Evidently, there is low advantages associated with national calculators and toolkits [49,50].

Importantly, each approach has many advantages, however, they also have many limitations to measuring emissions (Tables 10-11). The main limitations found in most of the calculators, toolkits and approaches are interlinked due to a lack of data, and incomplete system boundaries and scope of measurements [51-53]. For instance, 84% of the approaches are limited in the emissions that they measure which is also evident in (Tables 5,6). Meaning, that most of the approaches risk underestimating tourism emissions because the system boundaries are not thoroughly described and assessed. Additionally, this study identified that 68% of the approaches do not consider potential end-use emissions or land-use change impacts and are not suitable for individual use or national and regional use [54].

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Table 6: Comparing the advantages of the approaches available to measure emissions.

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustainable Travel International	Earth Check	Hotel Carbon Measurement Initiative	Weeva	SME Climate Hub	CARMACAL
Identifies & prioritises sustainability issues, flags the need to increase sustainability options & suggests actions					X		X	X	
Free for individuals and micro-businesses only and compares your carbon footprint with the average person in your country	X								
Flexible system that can be adapted to the needs of destinations and easy to compare results internationally							X		
Free access, user friendly, can be adjusted and 'ready to employ'	X	X	X	X	X	X		X	
There are videos/ guides on how to work the calculator on their website		X			X	X	X	X	X
Estimates emissions associated with supply chain and differentiated types of diets	X								
Includes emissions from distance uplift/ radiative forcing	X								
Differentiates between international and domestic tourists and identifies tourists travelling together	X								X
EPA recommended, and it considers emissions by the type of flight (domestic, short/ long haul), seat class and average occupancy	X								
Regularly updates data	X	X			X	X	X	X	X
Advises on reducing carbon footprints/ offset projects	X		X		X		X	X	X
Won an award and can enter specific itinerary details per day, and it will save data									X
Gives a breakdown of total carbon emissions into categories	X			X	X	X	X	X	X
Linked to Google Maps- easily finds the distance									X
Potentially a much greater accuracy							X		
Quantifies the linkages between tourism's contribution to the economy and its impact on emissions									
Data already collected & identifies consumption patterns					X				
Pinpoints emission hot spots and predicts changes if alternatives are chosen									
Enables a national tourism carbon inventory to be comprehensive and compatible with the System of National Accounts									
Can be implemented at single-region or multi-region		X			X	X			
Comparable nationally, as based on the Tourism Satellite Accounts									
More accurate and comprehensive							X		

Source adapted and modified: [13,15,31-43].

Table 7: Comparing the advantages of the approaches available to measure emissions (continued).

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustainable Travel International	Earth Check	Hotel Carbon Measurement Initiative	Weeva	SME Climate Hub	CARMACAL
Integrates sustainability into macro-level policy framework and disseminates information on tourism, carbon emissions and social welfare									

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Measures the sectoral-level emissions within the Paris Agreement while linking it with the progress of Sustainable Development Goals									
Internationally recognised tool		X				X	X	X	
Contains detailed background information which explains the development of specific emission values	X	X				X	X	X	
Improves the accuracy by replacing monetary data with physical to solve price heterogeneity, reduces estimation errors and includes tourists' actual behaviours									
Reduces levels of uncertainty					X		X		
Increases effective target campaigns					X	X	X	X	
Most holistic method, capable of estimating the direct and the maximum extent of indirect GHG emissions from products and services									
Highlights yearly performance indicators, benchmarking and compared to regional averages					X	X	X	X	
Showcases financial savings when reducing emissions					X				

Source adapted and modified: [13,15,31-43].

Table 8: Comparing the advantages of the approaches available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches															
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Identifies & prioritises sustainability issues, flags the need to increase sustainability options & suggests actions	X		X		X					X						
Free for individuals and micro-businesses only and compares your carbon footprint with the average person in your country																
Flexible system that can be adapted to the needs of destinations and easy to compare results internationally	X											X				
Free access, user friendly, adjustable & 'ready to employ'	X	X	X	X	X	X	X	X		X	X	X				
There are videos/ guides on how to work the calculator on their website		X								X						
Estimates emissions associated with supply chain and differentiated types of diets																

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Includes emissions from distance uplift/ radiative forcing														X	X	
Differentiates between international and domestic tourists and identifies tourists travelling together	X			X			X		X				X	X	X	X
EPA recommended, and it considers emissions by the type of flight (domestic, short/ long haul), seat class and average occupancy																
Regularly updates data	X	X							X		X	X	X		X	X
Advises on reducing carbon footprints/ offset projects			X	X	X	X	X	X								
Won an award and can enter specific itinerary details per day, and it will save data																
Gives a breakdown of total carbon emissions into categories	X		X		X				X	X	X	X	X			X
Potentially a much greater accuracy											X	X	X		X	X
More accurate and comprehensive											X	X			X	X
Reduces levels of uncertainty										X	X	X			X	
Increases effective target campaigns													X			
Linked to Google Maps- easily finds the distance																
Internationally recognised tool											X	X				

Source adapted and modified: [13,15,31-43].

Table 9: Comparing the advantages of the approaches available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches															
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO_2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Quantifies the linkages between tourism's contribution to the economy and its impact on emissions														X		
Data already collected & identifies consumption patterns			X		X							X	X	X	X	X
Pinpoints emission hot spots and predicts changes if alternatives are chosen													X			
Enables a national tourism carbon inventory to be comprehensive and compatible with the System of National Accounts												X		X		
Can be implemented at single-region or multi-region									X		X	X		X	X	X

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Integrates sustainability into macro-level policy framework and disseminates information on tourism, carbon emissions and social welfare														X	X	
Comparable nationally, as based on the Tourism Satellite Accounts														X	X	
Measures the sectoral-level emissions within the Paris Agreement & linking it with the progress of Sustainable Development Goals														X	X	
Contains detailed background information which explains the development of specific emission values		X	X		X						X	X				X
Improves the accuracy by replacing monetary data with physical to solve price heterogeneity, reduces estimation errors and includes tourists' actual behaviours															X	
Most holistic method, capable of estimating the direct and the maximum extent of indirect GHG emissions from products and services																X
Highlights yearly performance indicators, benchmarking and compared to regional averages			X		X											
Showcases financial savings when reducing emissions			X													

Source adapted and modified: [13,15,31-43].

Table 10: Comparing the limitations of the approaches available to measure emissions.

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustainable Travel International	Earth Check	Hotel Carbon Measurement Initiative	Weeva	SME Climate Hub	CARMACAL
Underestimates the carbon footprint	X	X	X	X	X	X	X	X	X
Overestimates the carbon footprint									
Not explicitly made for tourism, time-consuming and accurate data required	X							X	
Not suitable for individual use					X	X	X	X	X
Not suitable for business use			X	X					
Not suitable for regional/ national use	X	X	X	X	X	X	X	X	
Life cycle analysis in building sector not rational, & variations in itineraries/ purchasing patterns make it difficult to accurately measure									
System boundaries not thoroughly described									
Inaccurate assumptions of maximum load factors & average occupancies from modes of transportation									

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Homogeneity: assumes all businesses use same standard of technology/ proportionally: implies impacts doubled if consumption of one service is doubled. Does not consider price fluctuations or capacity utilisation ratios									
Not able to breakdown energy consumption at business levels & reduces effective targeting of energy efficiency campaigns			X	X					
Applications in other countries made with caution	X								
Does not consider potential end-use GHGs or land-use change impacts		X	X	X	X	X	X	X	
Incomplete sectorial statistics and assumed linear relationships between sector outputs and environmental burdens									
Unable to address total life cycle emissions & indirect emissions from capital goods/ infrastructure		X	X	X	X	X			
Uncertainty as assumptions made for products/services. Precise calculations are difficult	X								X
Limited emissions / impact categories	X	X	X	X	X	X	X	X	X

Source adapted and modified: [13,15,31-43].

Table 11: Comparing the limitations of the approaches available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches															
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO_2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Underestimates the carbon footprint	X	X	X	X	X	X	X	X	X	X		X				X
Overestimates the carbon footprint														X		
Not explicitly made for tourism, time-consuming and accurate data required											X	X	X	X	X	X
Not suitable for individual use	X		X	X	X				X	X	X	X	X	X	X	X
Not suitable for business use	X	X				X	X	X	X							
Not suitable for regional/ national use		X	X	X	X	X	X	X		X	X					
Life cycle analysis in building sector not rational, & variations in itineraries/ purchasing patterns make it difficult to accurately measure													X			
System boundaries not thoroughly described	X											X	X	X	X	X
Inaccurate assumptions of maximum load factors & average occupancies from modes of transportation													X		X	X

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Homogeneity: assumes all businesses use same standard of technology/ proportionally: implies impacts doubled if consumption of one service is doubled. Does not consider price fluctuations or capacity utilisation ratios													X		
Not able to breakdown energy consumption at business levels & reduces effective targeting of energy efficiency campaigns			X	X		X		X					X		
Applications in other countries made with caution		X	X	X	X	X	X	X			X				X
Does not consider potential end-use GHGs or land-use change impacts	X	X		X		X	X	X	X	X		X			X	
Incomplete sectorial statistics/ assumed linear relationships between sector outputs & environmental burdens													X	X	
Unable to address total life cycle emissions & indirect emissions from capital goods/ infrastructure	X	X		X		X	X	X	X	X		X				
Uncertainty as assumptions made for products/services. Precise calculations are difficult												X	X	X	
Limited emissions / impact categories	X	X	X	X	X	X	X	X	X	X		X				X

Source adapted and modified: [13,15,31-43].

Surprisingly, there are low limitations associated with the approaches particularly with the third party carbon calculators and toolkits, 22% have medium levels of limitations to measuring emissions [55]. For example, the Wayaj IMPPACTTM Program and the Sustainable Travel International toolkits due to the complexity of the tourism industry, financial pressures and time-consuming etc. Compared to the national, international and supranational calculators, toolkits and approaches, 63% have medium levels of limitations to measuring emissions [56]. For instance, the Montenegro, Spanish and Indonesia calculators, and the EE-IO.

Tables 5-10 showcase that there are many advantages and limitations to utilising each approach to measure emissions but there are also many barriers to overcome to implement each approach (Tables 12-13). The main barriers to overcome that this analysis identified are the lack of available data, lack of awareness and familiarity with the approaches (100%), doubts about the credibility of the measurements (84%) and that it is time-consuming to complete an accurate measurement (48%).

Table 12: Comparing the barriers of implementing the approaches available to measure emissions.

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustainable Travel International	Earth Check	Hotel Carbon Measurement Initiative	Weeva	SME Climate Hub	CARMACAL
Lack of data, awareness, and familiarity with the toolkit	X	X	X	X	X	X	X	X	X
Lack of resources									
Requires interdisciplinary collaboration									X
Doubts on credibility	X	X	X	X	X				X
Financial pressure	X						X		X

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Time-consuming	X				X	X	X		
Challenges for macro-level data, uncertainty & estimation errors increase									
Complex/ unmanageable with large visitor volumes & lack of data	X								
Not designed for developing countries	X								
Various styles of the approach make comparisons difficult – no single standard									
Not designed for individual use					X	X	X	X	X
Tourism Satellites Accounts not available in every country									

Source adapted and modified: [13,15,31-43].

Table 13: Comparing the barriers of implementing the approaches available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches														
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO_2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Lack of data, awareness, and familiarity with the toolkit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lack of resources													X	X	X	
Requires interdisciplinary collaboration	X									X		X		X	X	
Doubts on credibility	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Financial pressure													X		X	X
Time-consuming	X								X	X	X	X	X		X	X
Challenges for macro-level data, uncertainty & estimation errors increase													X			
Complex/ unmanageable with large visitor volumes & lack of data													X			
Not designed for developing countries											X					X

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Various styles of the approach make comparisons difficult – no single standard														X		
Not designed for individual use	X		X		X				X	X		X	X	X	X	X
Tourism Satellites Accounts not available in every country														X	X	

Source adapted and modified: [13,15,31-43].

Importantly, there are low barriers to implementing the approaches. In terms of third party carbon calculators and toolkits, 22% have medium levels of barriers to implementing the approaches. For example, the recommended Environmental Protection Agency carbon footprint calculator and the CARMACAL due to the complexity of the tourism industry. Similarly, with the national, international and supranational calculators, toolkits and approaches, 38% have medium levels of limitations to measuring emissions [57]. For instance, the Bottom-up/ Life Cycle Analysis (LCA), the EE-IO, EE-IO LCA (Hybrid) and UK DEFRA GHG conversion factors -LCA (Hybrid).

From comparing the advantages, limitations and barriers to implementing each approach it is apparent that some of the approaches with the most advantages, also have the most barriers to overcome to implement (Table 14-15). Of the third-party approaches, the Earth Checks carbon calculator and Weeva toolkit have the most advantages and lowest limitations and barriers. It is worth noting that majority of the third party approaches have low levels of limitations and barriers to measuring emissions, this is possibly due to the simplicity of them (Table 14). However, most of these approaches do not account for the full scope of emissions [58]. Hence, risk underestimation of the environmental impact of tourism emissions.

Table 14: Comparing the advantages, limitations and barriers to implementing each approach available to measure emissions.

Criteria assessed	Third-party calculators & toolkits								
	Carbon Footprint Ltd.	Hotel Foot printing Tool	Wayaj	Sustain-able Travel Interna-tional	Earth Check	Hotel Car-bon Mea-surement Initiative	Weeva	SME Cli-mate Hub	CARMA-CAL
Advantages	L	L	L	L	M	L	M	L	L
Limitations	L	L	M	M	L	L	L	L	L
Barriers	M	L	L	L	L	L	L	L	M

Source adapted and modified: [13,15,31-43].

Note: L= lowest amount of criteria present; M= medium amount of criteria present (that is in between the lowest and highest amount); H= highest amount of criteria present.

Table 15: Comparing the advantages, limitations and barriers to implementing each approach available to measure emissions (continued).

Criteria assessed	National, international & supranational calculators, toolkits & approaches															
	European Tourism Indicator System	CO_2RISM calculator	Climate Toolkit 4 Business	Calculate CO_2	CO_2 calculator (Finland)	CO_2 calculator (Spain)	CO2 calculator (Málaga Costa Del Sol)	CO_2 Calculator (Indonesia)	Destination Carbon Footprint Tool	DestiMED	DEFRA GHG	UNCCC calculator	Bottom-up/ Life Cycle Analysis	Environmentally Extended Input-Output Analysis	Hybrid (Environmentally Extended Input-Output Analysis – Life Cycle Analysis)	Hybrid (DEFRA GHG - Life Cycle Analysis)
Advantages	L	L	L	L	L	L	L	L	L	L	L	L	L	M	L	M

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Limitations	M	M	L	M	L	M	M	M	L	L	L	L	M	M	M	M
Barriers	M	L	L	L	L	L	L	L	L	M	L	M	M	M	M	L

Source adapted and modified: [13,15,31-43].

Note: L= lowest amount of criteria present; M= medium amount of criteria present (that is in between the lowest and highest amount); H= highest amount of criteria present.

From the national, international and supranational approaches, the EE-IO approach has the most advantages to measure emissions and is internationally recommended. However, it has the most limitations and barriers to overcome (Table 15). Moreover, one of its most prominent barriers is that it cannot be implemented internationally since the Tourism Satellite Accounts are not available in most countries. According to by utilising a hybrid approach, limitations and uncertainty are reduced [58]. However, the findings of this analysis suggest that even though limitations might be slightly reduced, the barriers to implementing a hybrid approach are very high (Table 15). For instance, the EE-IO LCA (hybrid) and the UK DEFRA GHG conversion factors – LCA (hybrid). These approaches are not only resource-heavy and time-consuming, but they also require interdisciplinary collaboration due to the high levels of detailed data required to measure tourism emissions [59]. It is worth noting that none of the calculators, toolkit or approaches analysed in Tables 13-14 have high levels of advantages, limitation or barriers. Therefore, continuous improvements and development is necessary.

Conclusion

This paper clearly identified an international perspective on the relationship between tourism and climate change. This study has contributed new knowledge on outlining the limitations and barriers that tourism policymakers must overcome and minimize to ensure a standardized approach can be implemented to measure and compare tourism emissions internationally. In order to decarbonize tourism and mitigate climate change, as tourism is a significant contributor to emissions and cannot be considered sustainable unless it is actively decarbonising. In addition, has emphasized the importance of measuring the carbon footprint of tourism with a unified approach. Many researchers have stated that by utilising a hybrid approach, limitations and uncertainty are reduced in the carbon footprint calculations. However, the findings of this analysis suggest that the hybrid approaches have more limitations and barriers to overcome. For instance, the EE-IO approach has many advantages, but there are many barriers to implementing this approach also. This is typically due to the lack of tourism data. Thus, to minimize these barriers, tourism policymakers and planners should begin to collect more detailed tourism data to compile the Tourism Satellite Accounts at a national level. This would guarantee the utilization of a standardized approach. Importantly, a standardized approach to measuring tourism emissions could ensure that resources are allocated efficiently, evidence-based decarbonisation strategies are implemented, and that tourism is transitioning towards Net-Zero. Consequently, striving for sustainable destination management and contributing to the SDGs and the Glasgow Declaration on Climate Action in Tourism.

Future research directions

This research identified that the most applicable approaches are not available to implement internationally. Hence, future research could focus on developing an integrated approach as a practical tool as a starting-point to measure tourism emissions at a destination level with the data available. In order to highlight to tourism policymakers and planners the data gaps that need to be minimized to increase the accuracy of the measurement. This approach can be adapted for specific destinations. For example, a country like New Zealand may be affected more by the carbon footprint of long-haul travel distances. Compared to countries like Italy or Spain, which may have more short-haul visitors [60]. Regardless, there needs to be a global alliance that the carbon footprint of tourism should be measured and reported annually at a national level. Consequently, this will allow tourism policymakers and planners to compare international carbon footprints and establish if tourism is making the necessary emissions reductions.

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