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Measuring the carbon footprint of inbound tourism at a destination level

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Abstract
Destination's dependency on aviation leads to inbound tourists producing higher levels of emissions than domestic tourists. This paper aimed to measure the first baseline carbon footprint of inbound tourism at a popular island destination, without the Tourism Satellite Accounts. The environmentally extended input-output life-cycle analysis is the most favourable approach to measure tourism emissions. However, this approach cannot be applied internationally due to the lack of tourism data. Therefore, this study implemented an integrated bottom-up approach to successfully measure inbound tourism emissions. According to this study, inbound tourism to Ireland generates 11.78 MtCO2eq, this is a conservative estimate due to the assumptions made to overcome the data limitations. Nevertheless, this study contributes to the increasing body of knowledge on tourism emissions as it establishes Ireland's first baseline carbon footprint of inbound tourism and demonstrates the need to upskill the tourism industry to actively measure, monitor and manage tourism decarbonisation.

Keywords: Climate Change Policy; Tourism Policy; Tourism Emissions; Decarbonisation; Sustainable Destination Management.

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1. Introduction

This study aimed to measure the first baseline carbon footprint of inbound tourism to a destination, that has not compiled the Tourism Satellite Accounts (TSAs), by utilising an integrated approach. There is an urgent need to measure and report tourism emissions to establish evidence-based decarbonisation strategies for sustainable destination management (OPSTP, 2021; UNWTO, 2022). Tourism decarbonisation is the process of reducing or eliminating human-induced emissions to ease climate change impacts and transition towards a climate-neutral or Net-Zero economy before 2050 (Butler *et al.*, 2015). Decarbonisation is a complex and challenging procedure to achieve but it is essential to combat climate change and develop sustainably.

Recently, many countries have begun to discuss the development of low-carbon, Net-Zero, or climate-neutral economies to mitigate climate change and enhance the prosperity of a destination (Falatoonitoosi *et al.*, 2022). The European Union (EU) has continuously supported international efforts on climate action. The European Climate Law was developed to ensure that all EU policies contribute to the goal of reducing Europe's net emissions by at least 55% by 2030 and becoming climate-neutral by 2050 (EC, 2022). This means Member States are obliged to achieving net zero emissions by investing in green technologies and protecting the natural environment - failure to do so will result in financial constraints.

It is evident that climate change has penetrated the tourism industry and sustainable tourism policies, plans and strategies are imperative to become resilient, manage tourism impacts and remain competitive (Tervo-Kankare, 2011; Becken & Clapcott, 2011; McLoughlin & Hanrahan, 2021). However, unless tourism is contributing to global decarbonisation it cannot be considered sustainable. Globally, the tourism industry is continuously excluded from national emission reduction plans, tourism policy tends to be only a minor area of government policy initiatives, and national tourism plans are generally scarce and/ lack destination-specific decarbonisation policies, plans and strategies (Sun *et al.*, 2020; Scott, 2021a; Scott, 2021b; Conefrey & Hanrahan, 2022a). Hence, for tourism to actively play a role in global decarbonisation and transition towards a climate-neutral industry, tourism policymakers and planners must actively measure, monitor, and report tourism emissions (OPSTP, 2020; 2021; UNWTO,2022). Therefore, the level of tourism decarbonisation occurring can be identified and evidence-based tourism decarbonisation policies, plans and strategies can be implemented.

The theoretical contribution of this study was the establishment of the first baseline carbon footprint of inbound tourism to a destination by utilising an integrated bottom-up methodological approach - which can be easily replicated internationally. The methodological approach was conceptualised because many destinations do not have the necessary tourism data to compile the TSAs (Sun & Higham, 2021). The bottom-up approach focuses on direct emissions from tourist activity data (Becken & Higham, 2021). However, when integrated with the Environmental Protection Agencies (EPA) recommended carbon calculator, the level of accuracy is increased as indirect emissions are measured (DBEIS, 2021). Additionally, the emission intensities derived from international studies were included to overcome the lack of tourism data. Therefore, this study established a methodological approach for tourism destinations to utilise as a starting point to measure and report tourism emissions without the TSA. Additionally, by utilising the integrated approach, the limitations in national tourism statistics were highlighted (Sun & Higham, 2021; Becken & Higham, 2021). Hence, closing the knowledge gap in a destination by identifying the emission-intensive areas in tourism and the data limitations.

2. Literature Review

Tourism encourages the movement of millions of people annually and provides economic benefits to destinations, particularly rural communities. However, tourism is a climate exposed industry that suffers greatly from economic damages related to climate change impacts (IPCC, 2023). Yet, tourism accelerates climate change as it produces significant levels of emissions which heavily impacts the social and natural environments of destinations (Dogru *et al*., 2019; Mondéjar-Jiménez & Ferrari, 2022). Continued growth in emissions will be challenging for any economic industry (Gössling & Higham, 2021). According to the IPCC (2023),

> *"international climate agreements, rising national ambitions for climate action, along with rising public awareness are accelerating efforts to address climate change at multiple levels of governance".* (IPCC, 2023, p.18).

2.1 Tourism and climate change policy and planning

Tourism is a complicated industry that requires comprehensive planning at international, national, and regional levels to avoid unexpected impacts (Lew *et al*., 2004; Hall, 2008). The positive economic impacts of tourism have always been discussed and thrived for. However, the negative impacts of tourism, specifically the industry's significant contribution to global emissions, are often overlooked or under studied at a destination level due to data limitations (Gössling, 2013; Sun, 2014; Gössling *et al*., 2015; Fauzel & Tandrayen-Ragoobur, 2021; Mondéjar-Jiménez & Ferrari, 2022; Conefrey & Hanrahan, 2022a; Hu, 2022). Consequently, climate action and decarbonisation or low-carbon policies are often not targeted at the tourism industry (Yang *et al*., 2022). Hence, additional research is needed to minimise the knowledge gaps regarding tourism emissions at a destination level. In order to enhance sustainable tourism development in policy and planning with a strong focus on climate action.

Policy agendas are currently being set through two distinct channels such as the Nationally Determined Contributions (NDCs) which intends to achieve the aims of the Paris Agreement, and the National Sustainable Development Strategies which intends to achieve the Sustainable Development Goals (SDGs) by 2030 (Dzebo *et al*., 2019). The Paris Agreement, a legally binding treaty on climate action, was adopted and requires nations to submit an updated national climate plan every five years. With the aim of intensifying ambition to regulating emission reduction targets and providing numerous adaptation measures that promote sustainable development (Jung *et al*., 2016; Dzebo *et al*., 2019). Hence, it is vital that the tourism industry contributes to decarbonisation to limit global warming by developing long-term strategies and evidence-based reduction targets consistent with the Paris Agreement.

The United Nations established the 17 (SDGs) for the world to utilise as guidelines to successfully transition towards sustainable development by 2030. The goals highlight the need for global collaboration and cooperation between all destinations and stakeholders to achieve economic, social, and environmental objectives (UN, 2023). According to Dwyer (2022), the United Nations World Tourism Organisation (UNWTO) has acknowledged that tourism can successfully contribute to the achievement of the SDGs 2030 agenda. However, despite the growing knowledge within tourism on the SDGs, studies constantly highlighted that there is a lack of awareness and understanding of climate change and action amongst society (Miléř and Sládek, 2011; Johnston, 2018; Kolenatý *et al*., 2022; Conefrey & Hanrahan, 2022a). This is worrying, as *Goal 13 Climate Action* of the SDGs can impact the successful completion of several other SDGs due to their high level of interconnectedness (Miléř & Sládek, 2011; Johnston, 2018). Therefore, the implementation of Goal 13 climate action must significantly increase to meet the 2030 agenda.

2.2 Tourism emissions

Tourism emissions data allow policymakers and planners to identify carbon-intensive areas and monitor the level of decarbonisation occurring annually. Transport accounts for the largest share of emissions generated from tourism (Lenzen *et al*., 2018; UNWTO, 2019). Furthermore, international aviation is one of the main contributors to tourism emissions, especially at island-based destinations (Gössling *et al.*, 2015; Becken & Higham, 2021; Sun *et al.*, 2022). International aviation emissions are expected to grow drastically due to the dependency on low-cost airlines, growing populations, increasing incomes, and the rise in urban living (Higham *et al.*, 2018; Becken & Shuker, 2019; Gössling *et al.*, 2019; Gössling & Lyle, 2021). To date, national emission frameworks exclude international transportation emissions (UNWTO, 2019).

Currently, available estimates of tourism emissions range from 8-11% of total global emissions (WTTC-UNEP-UNFCCC, 2021). Lenzen *et al.* (2018) estimate that global tourism produced between 3.9-4.5 Gt CO2eq (or 8% of global emissions) – excluding short-lived emissions from aviation. Mitigation policies and adaptation planning are key for a decarbonising world, as there is evidence of several countries achieving emission reductions for over a decade, as stated in the IPCC's sixth assessment report (IPCC, 2023). Hence, tourism has a substantial role in measuring and monitoring tourism emissions. In order to establish evidence-based decarbonisation policies and plans to facilitate the transition towards a Net-Zero economy before 2050.

Under the Paris Agreement, international aviation emissions are covered by the International Civil Aviation Organization (ICAO), which is a specialised agency of the United Nations. Nevertheless, tourism academics believe that international aviation emissions should be included in national emission frameworks, as it would be untransparent not to disclose them (Sun, 2014; Becken & Higham, 2021). Additionally, Lyle (2018) argues that international aviation should be brought under the direct responsibility of states as it would bring many advantages. For example, transcendence of the silos, individual governments decide on emission-mitigation measures, and each country would be in a position to create incentives or impose sanctions on air carriers. Consequently, including international aviation emissions in national frameworks will account for the actual environmental externality of tourism growth and encourage the implementation of location-specific decarbonisation policies, plans and strategies.

2.3 Approach to measure tourism emissions

Many academics have measured and reported tourism emissions using different timescales, approaches, system boundaries and scope of impact due to data limitation, as seen in Table 1. Evidently, there is a serious need for a standardised approach and system boundaries to be utilised, as barriers are created which prevents governments from comparing national tourism emissions internationally.

The two main approaches utilised focus on the bottom-up and top-down methodological approaches. There has also been an increase in utilising online toolkits and calculators, in the past, the credibility of these methods has been questioned. However, they are recognised as easy and accessible options to outline emission-intensive areas and educate users on strategies to reduce or offset emissions (Filimonau, 2011; Hanrahan *et al.*, 2018). For example, the European Tourism Indicator System (ETIS) as one of the core indicators is to measure the carbon footprint of visitors travelling to a destination (Hanrahan *et al.*, 2018). Additionally, there are other online toolkits and calculators such as the Environmental Protection Agencies (EPA) suggested carbon footprint calculators and the UK DEFRA GHG conversion factors.

The bottom-up approach accounts for emissions based on tourists actual behaviour. This approach is considered extremely accurate, however, it can be relatively time-consuming as it requires large amounts of detailed data and resources to complete the analysis. Typically, this approach is combined with the life-cycle analysis to increase the level of accuracy. It measures both the direct and indirect emissions of products or services from the production, consumption and disposal stages (Sun, 2014; Rico *et al.*, 2019). In general, most tourist destinations gather tourism activity data annually. Therefore, the bottom-up approach is recognised as a suitable starting point for most destinations to measure emissions.

Table 1. *Comparing tourism emissions studies at a destination level*

Destination & timeframe of data utilised	Method, scope of impact & unit of measurement	Average tourism emissions	Average tourism emissions per tourist
New Zealand (1997-98)	Top-down input-output (TSAs): Direct, indirect & imports (CO_2)	6.8 $MtCO_2$	-
Switzerland (1998)	Bottom-up & Top-down input-output (TSAs): Direct (CO_2eq)	2.29 - 2.62 $MtCO_2eq$	-
Australia (2003-04)	Production-based approach (TSAs): Direct, indirect & imports (CO_2eq)	54.4 $MtCO_2eq$	-
New Zealand (1997-98)	Top-down input-output (TSAs) and life cycle analysis: Direct (CO_2)	2689 $ktCO_2$ (energy only)	-
Taiwan (2007)	Top-down input-output (TSAs): Direct, indirect & imports (CO_2eq)	15 $MtCO_2eq$	-
Spain (2007)	Top-down input-output (TSAs): Direct, indirect & imports (CO_2eq)	63129 $ktCO_2$	-
Iceland (2011 Summer)	Bottom-up with life-cycle analysis: Direct (CO_2)	-	50.2 $kgCO_2$/per day
Iceland (2010-15: 2013 for average tourist)	Environmentally extended input-output life-cycle analysis (TSAs): Direct & indirect (CO_2eq)	6.4 $MtCO_2eq$	1350 $kgCO_2eq$
Antarctica (2008-09)	Bottom-up (only): Direct (CO_2)	198,843 Tons CO_2	490 $kgCO_2$
Japan (**2017**)	Top-down input-output (TSAs) and life-cycle analysis: Direct & indirect (CO_2eq)	136 Mt CO_2eq	-
Netherlands (2019)	Bottom-up (only): Direct & indirect (CO_2)	18.1 $MtCO_2$ -	52$kgCO_2$/per day - 455$kgCO_2$/per trip
China (2016)	Data envelopment analysis (DEA) & Input-output: Direct & indirect (CO_2)	268.38 $MtCO_2$	-
China (1997-2010)	Economic-Environmental Accounts (EEA): Direct, indirect & embodied (CO_2)	32.39-47.43 $MtCO_2$	-

Adapted and modified: (Sun, 2014; Luo *et al.*, 2019; Zha *et al.*, 2020; Eijgelaar *et al.*, 2021; Conefrey & Hanrahan 2022a; Hu, 2022).

In contrast, the top-down input-output approach focuses on managing the economy's economic data against the environmental accounts by utilising a statistical tool such as the TSAs, which tracks the demand for tourism goods and services (Dwyer *et al.*, 2010; Sun, 2014). This approach is recommended internationally because it estimates both the direct and indirect emissions from tourism, requires less time and is better for measuring the emissions of macro-systems. However, this approach disregards the life-cycle stages of a product or service. Additionally, there are matters of imperfection and truncation errors with this approach due to the analysis assuming historical tourist behaviour is still relevant (Lin *et al.*, 2013). Nevertheless, this approach is practical if a destination has compiled the TSA. However, many countries have not compiled them due to gaps in data collection (EU, 2019; CSO, 2019a). Therefore, barriers to implementing this approach at an international level are created.

Hybrid approaches are commonly used in international studies, as they are considered the most accurate. Within the literature, two-hybrid approaches were identified, the environmentally extended input-output life-cycle analysis (EEIO-LCA) and the UK DEFRA - life-cycle analysis. The EEIO-LCA approach synthesises the data and strengths of the bottom-up life-cycle analysis and the top-down input-output approaches. This is the preeminent approach for measuring tourism emissions accurately as the imperfections and uncertainties of utilising only one approach are reduced (Sun, 2014). For instance, replacing historical economic data with physical data to solve price heterogeneity. Although this approach has the most advantages when implemented, it is indisputable that it also has the most barriers to overcome for it to be implemented internationally (Conefrey & Hanrahan, 2022a). The second hybrid approach is the UK DEFRA - life-cycle analysis, which measures direct emissions produced from fuel burning and energy use, and indirect emissions linked to the fuel chain (Filimonau *et al*., 2013). Furthermore, this approach utilises the life-cycle analysis to measure the indirect emissions generated from producing energy, transport infrastructure and capital goods.

3. Materials and methods

Based on the literature review, the researchers acknowledge the advantages, limitations, and barriers of implementing each methodological approach utilised to measure tourism emissions (Conefrey & Hanrahan, 2022a). From comparing the approaches, the researchers developed an integrated bottom-up approach to measure tourism emissions without the TSA as many destinations have not yet compiled them due to the lack of data. The approach was developed by integrating the bottom-up approach with the EPA recommended carbon calculator and the average carbon intensities derived from international literature. Measuring and reporting tourism emissions is essential to ensure tourism policymakers and planners have sufficient sources of evidence to establish appropriate decarbonisation policies, plans and strategies (Hanrahan *et al*., 2018; Becken & Higham, 2021). Thus, minimising the knowledge gap in tourism policymaking.

According to Gössling and Higham (2021), to discuss the implications and opportunities for tourism in a decarbonising world, a destination focus is best suited. Hence, for the purpose of this research, a destination approach was utilised in Ireland as the researchers are employed and residents of Ireland. Meaning, the researchers have direct access to the available secondary tourism data and tourism stakeholders to collect and analyse the tourism emissions data. Additionally, the researchers have the ability to collaborate with national tourism bodies to minimise data limitations.

3.1 An island-based destination- Ireland

Ireland has eagerly embarked on tourism growth and development since the economic crash in 2009. From extensive destination marketing and investment, inbound tourists to Ireland increased from 6.1 million in 2010 to 10.8 million in 2019 (CSO, 2012; 2020). Based on the Organisation for Economic Co-operation and Development (OECD) report (2018), tourism has played a significant role in Ireland's economic renewal since 2011. Inbound tourist expenditure in Ireland increased from €3.5 million (2010) to €6.8 million in 2019 (CSO, 2012; 2020). However, the expenditure is not additionally presented per tourist per day, which causes barriers to assess the "value" and the "burden" of an individual tourist by region of origin. This information would allow one to estimate, for example, how many "valuable" tourists would be required to replace one "burden" tourist. Nevertheless, it is evident that tourism remains one of the most important economic sectors in Ireland.

From a critical analysis of national policies, plans and strategies that focus on climate action, it is evident that Ireland continuously excluded the tourism industry (Conefrey & Hanrahan, 2022a). The Climate Change Advisory Council (2022) highlighted that Ireland must build on tourism and climate action planning, as national tourism plans generally lack climate action. With the continuing growth of inbound tourism in Ireland and the high dependency on the aviation sector the Department of Tourism, Culture, Arts, Gaeltacht, Sport, and Media (DTCAGSM), Fáilte Ireland (National Tourism Development Authority) and other tourism bodies should recognise the importance of measuring, monitoring, and reporting tourism emissions. In order to develop evidence-based decarbonisation policies, plans and strategies to mitigate carbon risks. Although Ireland's national tourism plans support a sustainable approach, there is a lack of emphasis on evidence-based climate action content or decarbonisation actions. Given the potential impacts of climate change, tourists with high carbon footprints could hinder the Irish economy from transitioning towards a climate-neutral economy by 2050 and have financial consequences.

Within Ireland, the Climate Action and Low Carbon Development (Amendment) Bill 2021 reinforces Ireland's commitment to achieving a climate-neutral economy by 2050. This legally binding framework sets clear targets in law, to ensure Ireland achieves its climate action obligations (Jensen, 2021). The DTCAGSM and Fáilte Ireland are responsible for providing a strategic pathway for the public and private sectors to develop and manage tourism sustainability. Thus, the Ministers of the departments and Fáilte Ireland may suggest and propose new or amended tourism policies, legislation, and regulations to the government.

In 2019, Ireland was responsible for emitting 59.8 $MtCO_2eq$. The agricultural industry is the primary contributor to Ireland's emissions, however, emissions from international transport, land use and forestry sectors were excluded. Ireland is a popular island-based destination that is heavily reliant on aviation. To date, there is no evidence of tourism emissions being measured, monitored, and reported at a national scale in Ireland and Ireland has not yet compiled the TSAs due to the lack of data (CSO, 2019a; EPA, 2022). Thus, preventing Ireland from monitoring the level of decarbonisation occurring regularly.

Previous studies have measured the direct emissions from tourists travelling to specific regions in Ireland by utilising the ETIS approach. It was identified that inbound, domestic and same-day tourists travelling to the regions Clare, Sligo and Donegal generate between 118 - 218 $kgCO_2$ (McLoughlin *et al*., 2018; Hanrahan *et al*., 2018; McLoughlin *et al*., 2020). However, when domestic and same-day visitors are excluded from the measurement, the emissions for inbound tourists increases and ranges from 229 – 333 $kgCO_2$ (Hanrahan *et al*., 2018). However, the researchers of this study highlighted that the ETIS has many limitations when calculating the carbon footprint of tourism. For instance, the ETIS measures direct emissions from one-way trips and includes transportation only, and the ETIS calculation of CO_2 emissions was problematic at the time of the research (McLoughlin *et al*., 2018; Hanrahan *et al*., 2018; McLoughlin *et al*., 2020; Conefrey & Hanrahan, 2022a). Hence, these previous studies utilised the EPA recommended carbon calculator instead and calculated the emissions of a return trip to coincide with other international studies. Therefore, this study utilises an integrated approach as a starting point to provide the first baseline carbon footprint of inbound tourism in Ireland at a destination level. Outbound tourism is excluded from the measurement to avoid double counting, however, a conservative estimate is provided to show the impact of international transport on emissions.

3.2 Approach

Figure 1 provides an overview of the approach and formula implemented in Ireland to measure tourism emissions. Hence, reducing the knowledge gaps in tourism policymaking and providing an evidence-based approach to tourism decarbonisation.

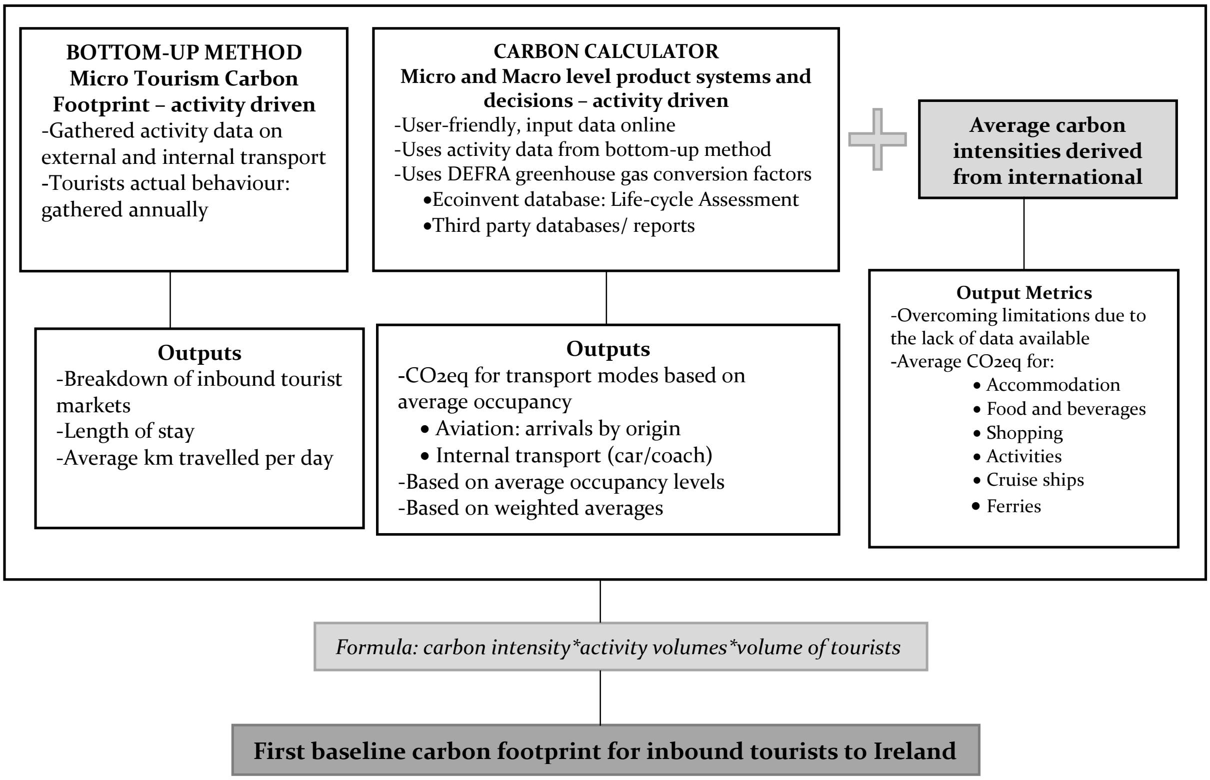


Figure 1. *An overview of an integrated bottom-up approach to measure inbound tourism emissions in Ireland*

Source adapted and modified: (Becken, 2009; Howitt *et al*., 2010; Eijgelaar *et al*., 2010; Virtanen *et al*., 2010; Murphy-Bokern, 2010; Filimonau *et al*., 2011; Åkerman, 2012; Franchetti *et al*., 2013; Filimonau *et al*., 2013; Yin, 2013; Sun, 2014; Sharp *et al*., 2016; Heller *et al*., 2018; DCHG, 2018; Becken & Shuker, 2019; Larsson & Kamb, 2019; CSO, 2019b; Cheng *et al*., 2020; Hjorth *et al*., 2020; Kitamura *et al*., 2020; DRCD, 2020; CSO, 2020; Becken & Higham, 2021; Conefrey & Hanrahan, 2022; Shorter, 2021; CSSUM, 2022; West, 2021).

Previous literature has praised the bottom-up approach for its accuracy, consistency and transparency when combined with the life-cycle analysis (Lin *et al*., 2013; Sun, 2014). According to Becken and Higham (2021), when utilising the bottom-up approach, emissions from key tourism sectors need to be analysed independently. Therefore, this study followed three critical steps to examine the emissions individually. The first step identified the 'system boundaries' within the scope of measurement (Table 2). The second step utilised Ireland's tourists activity data. The third step disaggregated inbound visitor activity into the different tourist markets and determined the contribution of each market. Thus, this approach provides insights into business operations and potential tourism decarbonisation strategies that can be implemented in Ireland.

Table 2. *System boundaries to measure inbound tourists emissions in Ireland*

Stages of tourism	Components of tourism consumption	Unit of measurement	Scope of impact	Timeframe of measurement
		Inbound tourists to Ireland		
• During tourism	• Aviation • Marine (external and internal) • Internal private transport • Internal public transport • Accommodation • Food and beverages • Amenities/ Activities • Shopping	• CO2eq	• Direct • Indirect	• Year

The EPA (2022) recommends using the '*Carbon Footprint Calculator*', which measures direct and indirect emissions from Scope 1 and Scope 2 (see Table 2) (https://www.carbonfootprint.com/calculator1.html). The calculator utilises data from the UK DEFRA GHG conversion factors, Ecoinvent database, credible third-party databases, and reports, and it is ISO 9001:2015 certified (DBEIS, 2021). The UK DEFRA GHG conversion factors have independent accounting and reporting standards to measure emissions of products and services (Filimonaua *et al*., 2013). The Ecoinvent (2022) database is a life-cycle inventory database that supports various sustainability assessments and evaluates emissions from all stages (i.e., production, use, and disposal). The life-cycle analysis has the ability to measure the emissions of an individual, industry, organisation, community, or nation (Sun, 2014; Rico *et al*., 2019). According to the International Organisation for Standardisation (2018), ISO 9001:2015 data provides internationally agreed principles, requirements, and guidelines for measuring the emissions of a product.

Table 2. *Scope of impact categories*

Scope 1 (Direct emissions from an activity that individuals have no control over)	**Scope 2** (Indirect emissions from generation of electricity somewhere else and brought to the place of consumption)	**Scope 3** (Other indirect/ induced emissions from the manufacture and delivery of purchased goods and services, e.g., food/ souvenir production)
• Fuel combustion • Owned transport • Process emissions • Fugitive emissions	• Consumption of purchased electricity, heat, steam, and cooling	• Purchased materials and fuels • Transport-related activities (staff travel/ supply chain emissions) • Waste disposal • Leased assets, franchising, and outsourcing • Sold goods and services

Source: (Sun, 2014; Sharp *et al*., 2016; Becken & Higham, 2021).

There is a lack of consistent and transparent tourism activity data in Ireland. Therefore, to overcome this limitation, the average carbon intensities for specific tourism sectors were derived from international literature and from collaborating with tourism academics (Sun,2014; Sharp *et al*., 2016; Kitamura *et al*., 2020; Becken & Higham, 2021). Thus, until the TSA are available in Ireland, this integrated approach will be a starting point to measure, monitor and report Irish tourism emissions.

3.3 Data sources

This study primarily drew on secondary data from 2019 relating to the number of inbound tourists who stayed at least one night in Ireland and cruise ship passengers that disembarked at Irish ports. Data for inbound tourists in Ireland was obtained from Ireland's Central Statistics Office, Fáilte Ireland, and Irish Car Rental Council (ICRC). The data obtained was visitor volume, country of origin, length of stay, mode of transport to arrive in Ireland and mode of transportation to travel around Ireland (CSO, 2019b: 2020; Fáilte Ireland, 2021). According to this data, in 2019, inbound tourists to Ireland reached 10.8 million and there were 432,443 cruise ship passengers to Ireland. In order to capture the emissions produced by inbound tourists, it was necessary to make assumptions in some areas due to data limitations. The potential errors arising from the assumptions are discussed in the limitations and future research section.

In Ireland, inbound tourists are heavily dependent on aviation, however, there is no data available on the tourists choice of departure airport or port in their country of origin. Therefore, it was necessary to complete catchment areas. The catchment areas were developed based on direct flights to Dublin or flights from long-haul regions with the least number of connections and the busiest airports in the countries of origin. Dublin airport is selected as the primary airport for tourist arrivals in this analysis, as it received the highest volume (85.7%) of arrivals in 2019 (CSO, 2020). Once the catchment areas were identified, a weighted average could be formulated to assist with a robust calculation.

The carbon calculator was utilised to determine the emission intensity of return trips for each market. The calculator uses the greater circle approach to calculate the distance between the airports selected, then it is multiplied by the emission intensity for that specific type of flight (Carbon Footprint Ltd., 2022). The average emission intensity of a flight differs depending on the per passenger-kilometre travelled and the seat class taken. The average emission intensities include the distance uplift to compensate for flights not travelling the most direct route, assuming an average plane occupancy, and dividing the emissions between the occupants into various seat classes. Furthermore, the emission intensities can include the influence of radiative forcing which is the impact of emissions in the upper troposphere.

In Ireland, very few tourists avail of the international maritime transport sector, however, to be transparent, it is still necessary to assess these emissions (CSO, 2019b; 2020; Fáilte Ireland, 2021). Due to the lack of data regarding tourists departure and arrival ports, it was necessary to get the average distance travelled from popular routes. For ferries, the average distance travelled is based on direct ferries from departure ports in Britain, France, and Spain to arrival ports in Ireland (Dublin, Cork, and Rosslare). The average emissions intensity for ferries was generated from the UK Department for Business, Energy and Industrial Strategy Greenhouse Gas Conversion Factors and the Global Warming Potential (Åkerman, 2012; West, 2021). The emission factors include both foot passengers and vehicle passengers.

For cruise ship tourists, the average distance travelled was calculated based on cruise ships arriving and departing from Irish ports (Eijgelaar *et al.*, 2010; Howitt *et al.*, 2010; CSO, 2019b; Simonsen *et al.*, 2019; Becken & Higham, 2021). It was necessary to make assumptions regarding cruise routes that disembark at Irish ports. Thus, establishing an average distance travelled by cruise ship routes from the USA and Europe. Due to limited research, the emission intensity from cruise ship tourism is difficult to quantify. Nevertheless, the emission intensity was taken from Carnival Cruise ship's sustainability reporting and research conducted on different size cruise vessels (Simonsen *et al.*, 2019; Becken & Higham, 2021). However, any assumption carries a level of uncertainty, and the approach presented in this analysis will require refinement in the future.

Minimal data is available on the internal mobility patterns of tourists in Ireland. Data on inbound tourists' land mobility activity was obtained from the ICRC and Fáilte Ireland. The ICRC (personal communication, July 8, 2021) provided the average distance travelled, and this distance was assumed for other modes of transport used (rail or coach). Fáilte Ireland (2021) provided information on the proportion of inbound tourists that travelled by car or did not travel by car. Tourists internal marine mobility activity data to offshore islands were acquired from the Department of Culture, Heritage, and the Gaeltacht and the Department of Rural and Community Development (DCHG, 2018; DRCD, 2020). Little data is available on the tourist markets that travel to the offshore islands. Therefore, a weighted average was calculated to determine the total proportion of inbound visitors that utilised this transport service.

The EPA suggested carbon footprint calculator provides emission intensities for various types of vehicles (Carbon footprint Ltd., 2022). A standard car that operates on fossil fuels was assumed. Additionally, based on the literature, it was assumed that for private vehicles, there was an average occupancy rate of at least two passengers (Becken, 2009; Åkerman, 2012; Larsson and Kamb, 2019; Becken and Higham, 2021; CSSUM, 2022). Therefore, the emissions intensity of a vehicle was divided by the average occupancy.

Ireland lacks consistent and transparent data on tourism emission intensities for accommodation, food and beverages, shopping, and activities. Therefore, it was decided to derive and collate specific emission intensity estimates from international literature (Virtanen *et al*., 2010; Murphy-Bokern, 2010; Filimonau *et al*., 2011; Filimonau *et al*., 2013; Sun, 2014; Sharp *et al*., 2016; Heller *et al*., 2018; Cheng *et al*., 2020; Hjorth *et al*., 2020; Kitamura *et al*., 2020; Becken & Higham, 2021). The different international studies highlight the diversity of emission factors due to geographic location, production and business type, product or service type, and various other factors. Therefore, it is essential that Ireland provides emission intensities for each sector within the tourism industry to reduce limitations and barriers to future calculations.

4. Results

In 2019, Ireland's emissions were 59.8 MtCO2eq, this excludes international transport (CSO, 2020; EPA, 2022). The findings of this study identified that the inbound tourists emitted 11.78 MtCO2eq in 2019. This is a conservative estimate due to the assumptions that were made. According to the assessment, the average emissions of an inbound tourist ranges from 880-1,067 kg CO2eq/per tourist per return trip depending on the distance travelled and mode of transport utilised. When combined with Ireland's outbound tourism emissions (7.56 MtCO2eq), Ireland's international tourism emissions (19.34 MtCO2eq) were nearly equivalent to the agricultural industry (21.1 MtCO2eq) (Conefrey & Hanrahan, 2022b). In Ireland, the agricultural industry emissions have continuously been measured, monitored, and reported annually and included in national climate action policies, plans and strategies with strong efforts made to decarbonise the industry. Yet, tourism has constantly been excluded. Therefore, this finding highlights the importance of measuring, monitoring, and reporting tourism emissions and particularly the importance of including international transport in the emissions framework.

The contribution ratio of each sector is as follows: transport 78%, accommodation 13%, food and beverage 3%, shopping 4% and attractions or activities 2%. Similar to international literature, transport is the most significant contributor to tourism emissions, with 9.20 MtCO2eq. Within the transport sector, aviation generates the highest levels of emissions with 8.43 MtCO2eq (92%), followed by internal land and marine transport with 0.51 MtCO2eq (5%) and international maritime transport with 0.26 MtCO2eq (2%). The high aviation emissions are likely due to the high dependency on air travel and possibly the high visitor volumes that require long-haul and connecting flights.

The three main tourist markets that contribute to inbound tourists emissions are North America (51%), followed by Australia, New Zealand, and the Oceania regions (14%) and Other Areas (such as Asia, Africa, and Central America) (12%) (Figure 3). According to Becken and Higham (2021), it is helpful to contrast the number of inbound tourist arrivals with the aggregate emissions for one-way flights for each tourist market (Figure 4). From this comparison, it is evident that tourist arrivals from Australia, New Zealand and Oceania regions or Other areas produce higher emissions than their tourist volumes, due to the distance travelled and connecting flights. Therefore, these findings highlight that it is essential to understand the significant contribution long-haul flights make towards tourism emissions. In terms of modelling, it is fundamentally useful to make this comparison as it allows tourism policymakers, planners, and tourists to visualise the emissions impact of inbound tourists in Ireland.

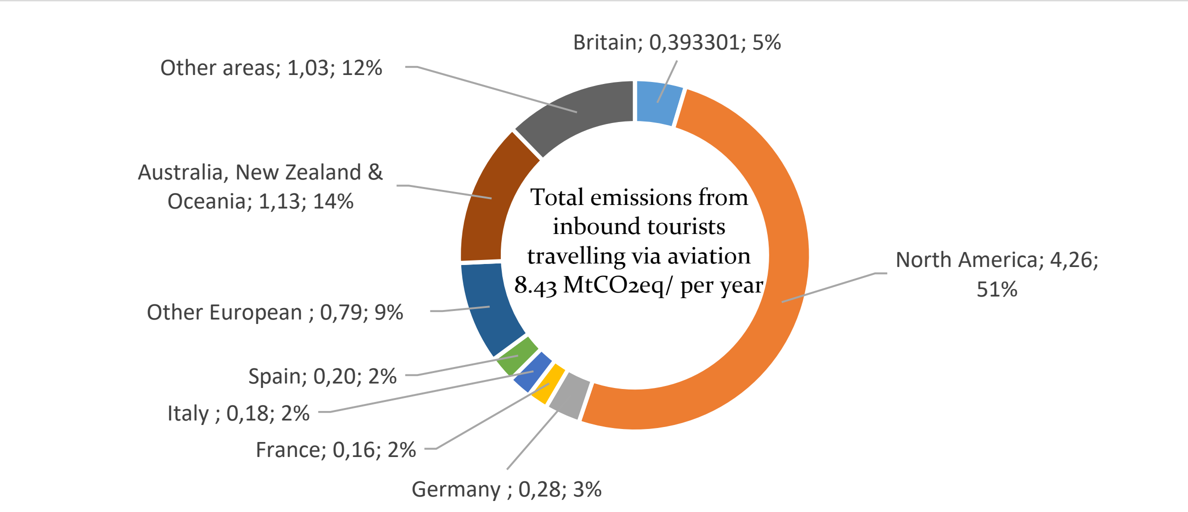


Figure 3. *Inbound tourists aviation emissions*

Inbound tourists travelling to Ireland have a substantial economic impact on the economy by generating income and employment in rural communities. Therefore, it is essential to compare the economic impact of inbound tourist markets against the emissions they produce to determine the value of each market, as seen below (Figure 5) (CSO, 2020). Due to the lack of data available on cruise ship passengers expenditure their economic impact cannot be compared against the emissions the markets produce. Nevertheless, from analysing the inbound tourist markets, it is evident that the North American market contributes the most expenditure and the most emissions per year (Figure 5). This is possibly due to the volumes of tourists from this market and length of stay. Therefore, the value of this market will be reduced due to the resources that will be required to offset or decarbonise these emissions.

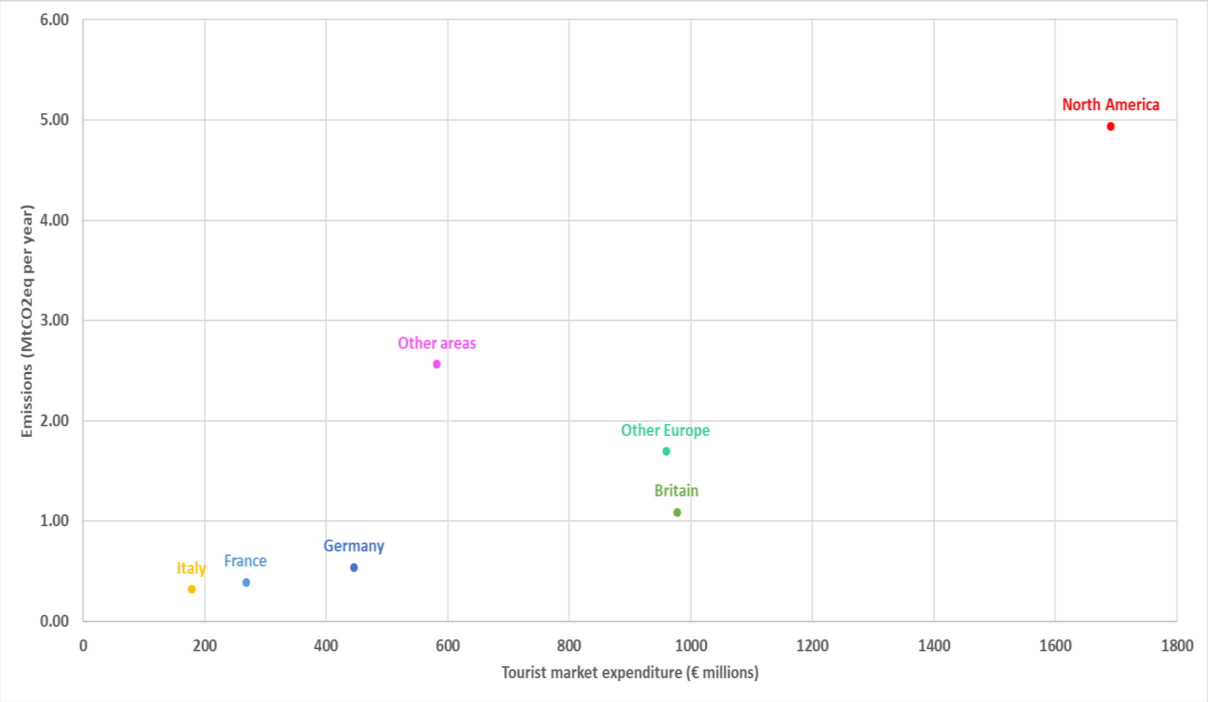
In order to monitor and manage tourism emissions, the industry needs to measure and report emissions annually. This data is useful to policymakers and planners as it enables them to establish evidence-based policies and strategies for sustainable destination management. Thus, the Irish tourism industry can future-proof its international tourist markets.

5. Discussion

For tourism to be considered sustainable and avoid accusations of greenwashing, the industry must measure and report tourism emissions annually to determine the level of decarbonisation occurring (Scott, 2021a; 2021b). The integrated approach developed within this study provides tourist destinations with a practical starting point tool to measure and report tourism emissions without the TSA. By implementing the approach in Ireland, the findings of this study produce the first baseline carbon footprint of inbound tourists in Ireland. Furthermore, the conclusions of this study are in line with other international literature studies, particularly island-based studies (Sun, 2014; Sharp *et al.*, 2016; Kitamura *et al.*, 2020; Becken & Higham, 2021; Sun *et al.*, 2022). The similar emissions found by the Icelandic (6.4 MtCO2eq/ per year and 1,350 kgCO2eq per tourist per trip) and Taiwanese (15 MtCO2eq/ per year) studies go some way towards validating the current analysis findings. Thus, this study supports the premise that this approach can be easily replicated in other destinations.

Figure 4. *Comparing Ireland's inbound aviation arrival numbers against emissions of a one-way flight*

Most destinations gather tourism data annually, such as visitor numbers, length of stay and total expenditure. However, tourism data tends to lack completeness and comparability (Sun, 2014; Rico *et al.*, 2019). The researchers found a wide range of knowledge gaps in Ireland's tourism data. In order to overcome these knowledge gaps, it was necessary to make assumptions based on international literature. Nonetheless, with any assumptions, a level of uncertainty is carried out (Becken & Higham, 2021). Therefore, this research contributes new knowledge by highlighting the areas where data collection and distribution must be refined to minimise the level of assumptions (Table 3). Consequently, other destinations can fine-tune the assumptions that were made.



**Excludes cruise ship passengers due to the lack of economic data*

Figure 5. *Comparing Ireland's inbound tourists total expenditure against total emissions*

Table 3. *Tourism data needs to be collected annually to reduce knowledge gaps*

Sector in tourism	Areas where data needs to be collected
Aviation and ferries	• Departing airport/ port in the country of origin • Arriving airport/ port in Ireland • Connecting flights • Seating class • Domestic flights • Foot passenger or vehicle passenger
Cruise ship	• Last departed country and port • Arriving port in Ireland • Itineraries • Last Irish port of call • Next country and port departing for • Cruise ship provider's emission intensities per km

Land transport	• Mode of transport
	  ○ Precise breakdown (i.e., private vehicle, bus, coach, train, taxi etc.)
	  ○ Private vehicle: make, model, fuel type
	• Compensation of tourist group
	• Itineraries (regions travelling to)
	• Average km per day

Domestic ferries	• Breakdown of the number of tourists • Departing and arriving ports • Foot passenger or vehicle passenger
Accommodation/ Food and Beverages/ Shopping/ Activities	• Stakeholder's emission intensities audits

The findings of this study are valuable as they emphasise the fundamental need for destinations to restart and rethink the way tourism data is gathered and distributed. For example, refining passenger locator forms in airports and ports. By collecting and producing more tourism data, policymakers and planners can transform this data to increase the accuracy of measuring emissions (Hanrahan *et al.*, 2018). Thus, enabling the industry to establish evidence-based and location-specific decarbonisation policies, plans and strategies.

6. Limitations and future research

The findings from this study are a conservative estimate due to data sources and methodological limitations. It is important to highlight the assumptions made to minimise them for future studies. Overall, the underestimation of inbound tourism emissions will likely outweigh the overestimation.
For the aviation sector, this study assumed that all flights were direct from Europe and North America and that all tourists flew in economy class, due to the lack of data. Furthermore, the national tourism surveys do not provide information on tourists chosen departure airports in their country of origin. Therefore, assumptions were made based on catchment areas and weighted averages. Thus, it leads to the possibility of underestimating aviation-related emissions.

The national tourism surveys do not provide information on inbound tourists chosen departure ports in their country of origin. Additionally, there is no information on the route itineraries for the maritime transport sector. Therefore, similar to the aviation sector, assumptions were made based on the direct ferries and cruise ships to Ireland and average emission factors from international literature. Additionally, it is stated that 1% of inbound tourists travel by ferry from mainland Europe (Fáilte Ireland, 2021). However, due to the lack of information regarding inbound tourists country of origin in mainland Europe, the emissions for ferries are over-estimated by 1%. Thus, assuming 1% travel from France and 1% travel from Spain. Furthermore, for internal marine transport to the offshore islands of Ireland, the exact sea distance from Irish ports to island ports is not available. Hence, this leads to the possibility of underestimating the distance travelled by internal marine transport and the related emissions.

The average distance travelled by internal land transport for inbound tourists was obtained from the ICRC. The average percentage of inbound tourists who utilised private cars was acquired from Fáilte Ireland (ICRC, personal communication, July 8, 2021; Fáilte Ireland, 2021). Additionally, it was assumed that tourists travelled the same distance each day for their entire length of stay. However, there is a possibility that tourists exceed this average distance or that they might not use internal transport every day. In addition to this, due to the lack of data regarding the average occupancy rate for private cars, this data was derived from international literature (Becken, 2009; Åkerman, 2012; Larsson & Kamb, 2019; CSSUM, 2022). Therefore, there is a possibility of over-estimating or under-estimating the emissions associated with private car use, as the travel distances can vary and the average occupancy rate in Ireland could be lower or higher than in international studies.

The average distance travelled that was obtained for private cars was also assumed for other forms of transport. Consequently, it was assumed that the remaining percentage of inbound tourists that '*did not use a car*' utilised some form of public transportation, such as coach or rail (Fáilte Ireland, 2021). However, if this remaining share mainly used taxis, then the emissions will be under-estimated. In contrast, emissions will be over-estimated if this remaining share mostly travels via bicycles or by walking. Furthermore, the emissions will also be over-estimated if tourists mainly use electric public transport as the carbon intensity is too high.

Overall, the reliability of the results from this study are assessed in terms of the limitations and uncertainties associated with the approach and data utilised. The applicability of the integrated approach is appropriate based on other international studies (Filimonau *et al*., 2013; Sun, 2014; Becken & Higham, 2021). The integrated approach was selected for numerous reasons, supporting its applicability. Firstly, Ireland has not compiled the TSAs, therefore, the top-down approach cannot be implemented and compiling the TSAs was outside the scope of this study due to time and financial constraints. Nevertheless, the bottom-up approach combined with the life-cycle analysis is known for its high accuracy levels. Secondly, the integrated approach enables enhancements by using data from national tourism surveys. In this assessment, utilising data on inbound tourists actual behaviour in the model will significantly reduce the compatibility uncertainty. Lastly, as Ireland lacks emission intensity data regarding key sectors in the tourism industry, deriving average emission intensities from international literature can overcome this limitation, thus, further improving the assessment.

Regarding the data utilised, inbound tourists travel patterns were predominantly sourced from Ireland's Central Statistics Office, Fáilte Ireland, Tourism Ireland, and the ICRC, which suggests a high level of reliability. Moreover, the impact of Ireland's inbound tourism emissions is a conservative estimate, with no specific emission intensity data on accommodation, activities, food and beverages, or shopping habits. Therefore, more refined data is required to improve this analysis in the future.

This study will allow for a much larger study of measuring tourism emissions at a national level and the development of a tourism decarbonisation toolkit to upskill the industry for a decarbonised world. More comprehensive, accurate and up-to-date data collection is needed on tourists actual behaviour to minimise the assumptions made. This information will provide the necessary data to compile the TSA.

7. Conclusion

For the tourism industry to actively transition towards Net-Zero emissions before 2050, this research contends that several key factors need to be urgently addressed. In terms of reskilling and upskilling to accurately measure and monitor tourism emissions to actively contribute to climate action (McLoughlin *et al*., 2018; Becken & Higham, 2021; Sun & Higham, 2021). This study aimed to measure the first baseline study on the carbon footprint of inbound tourism in Ireland, without the TSA. An integrated bottom-up approach was established and carries added value to the research field as it provides tourist destinations, that have limited tourism data, with a practical starting point tool to measure, monitor and report tourism emissions. Hence, directly contributing to previous researchers and global tourism leaders call to measure and report tourism emissions at a destination level to monitor the level of decarbonisation occurring regularly (OPSTP, 2020; 2021; UNWTO, 2022; UNWTO, 2021; Scott, 2021a; Scott, 2021b; Becken & Higham, 2021; Sun *et al*., 2022; Conefrey & Hanrahan, 2022a). The results of tourist destination emissions should not be interpreted as criticising the industry but rather viewed as demonstrating the use of science to measure, monitor, and manage tourism emissions.

It is expected that this study will contribute to the ongoing discussion of the importance of tourism decarbonisation for climate action, which is imperative to achieving sustainable tourism development (Miléř & Sládek, 2011; Johnston, 2018; Scott, 2021b; Gössling & Higham, 2021). According to previous studies, national tourism plans lack climate action and decarbonisation content and discussion at an international scale (Conefrey & Hanrahan, 2022a). Measuring and reporting tourism emissions regularly provides an opportunity for tourism policymakers and planners to develop evidence-based climate action policies and plans targeted at the tourism industry to aid the transition towards Net-Zero emissions (Tervo-Kankare, 2011; Becken & Clapcott, 2011; McLoughlin & Hanrahan, 2021; Yang *et al*., 2022; IPCC, 2023). Furthermore, implementing *Goal 13 Climate Action* of the SDGs can positively impact the successful completion of several other SDGs due to their high level of interconnectedness (Miléř & Sládek, 2011; Johnston, 2018). Hence, it is important that tourism policymakers, planners, enterprises and tourists themselves collaborate to decarbonise the industry for climate action.

One of the most pertinent implications this study has recognised is the necessity to improve tourism data collection and distribution at a national level. This valuable finding reflects similar calls for enhanced tourism data to reduce the knowledge gaps and minimise the level of assumptions required in future studies (Sun, 2014; Luo *et al*., 2019; Zha *et al*., 2020; Becken & Higham, 2021; Sun & Higham, 2021; Conefrey & Hanrahan 2022a; Hu, 2022). Consequently, increasing the accuracy of measuring tourism emissions to successfully contribute to informed decision-making that balances the needs of the tourism industry and climate action.

In this study, priority was given to showing the entire carbon footprint of inbound tourism to Ireland, including international transport emissions as it would be untransparent not to disclose them (Sun, 2014; Becken & Higham, 2021; Gössling & Lyle, 2021). While the examination of emissions generated by outbound, domestic, and northern Irish tourists visiting Ireland was outside the scope of this study, such an analysis would be beneficial in the future to fully comprehend and address the impacts caused by the rapidly growing tourism industry in Ireland.

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