GRIFFITH UNIVERSITY

Measuring tourism emissions at destination level: Australia case

Author

Pham, T, Meng, X, Becken, S

Published

2022

Journal Title

Annals of Tourism Research Empirical Insights

Version

Version of Record (VoR)

DOI

10.1016/j.annale.2022.100062

Rights statement

© 2022 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Downloaded from

http://hdl.handle.net/10072/422103

Griffith Research Online

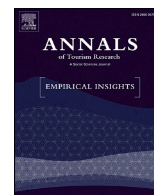
https://research-repository.griffith.edu.au

Annals of Tourism Research Empirical Insights 3 (2022) 100062

Contents lists available at ScienceDirect

Annals of Tourism Research Empirical Insights

journal homepage: www.sciencedirect.com/journal/annals-of-tourism-research-empirical-insights



Measuring tourism emissions at destination level: Australia case ☆

Tien Pham [a,*], Xianming Meng [b], Susanne Becken [c]

[a] Department of Tourism, Sport and Hotel Management, Griffith Business School, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia
[b] University of New England, Armidale, NSW 2350, Australia
[c] Griffith Institute for Tourism, G27 3.05, Gold Coast Campus, Griffith University, Queensland, Australia

ARTICLE INFO

Editor: Kirilova Ksenia

Keywords:
Carbon footprint
Tourism emissions
Tourism satellite account
Destinations
Carbon account framework

ABSTRACT

Decarbonising tourism is an immeasurable challenge but increasingly recognised as inevitable. This has prompted vast developments in theoretical models by academics and indicators by peak bodies to explore the pathways. One limitation to the pathways is the lack of emission data. This research presents a framework integrating the principles of TSA with the National Greenhouse Accounts. Tourism emissions are estimated and examined by destinations, producing industries and visitor types. The framework is applied to destinations in the State of Queensland, Australia, to illustrate the types of results and insights that can be produced for decision-makers. Mitigation policies can then be tailored to the specific context of each destination, increasing effectiveness and ability to balance economic benefits with reducing emissions.

1. Introduction

Tourism arises on the premise of experiences that visitors would like to explore outside of their usual environment, that could take them to a destination on the other side of the globe or just another region in their own countries. The experiences could involve explorations of social and cultural heritage, or visitations to appreciate natural or man-made beauty, as in the case of events or urban environments. Whichever way, tourism development has been a priority for many governments to generate revenue and employment through the visitor economy. However, the great success of tourism growth has raised increasing concerns about its social and environmental impacts, especially its carbon footprint (Lenzen et al., 2018). The concept of sustainable tourism development has sought to deliver solutions for maximising the economic potential of the sector while, at the same time, minimising its adverse impacts. The task to strike a balance has increasingly become so imperative that some have called for a complete transformation of the tourism system: its purpose, design and delivery (Becken & Kaur, 2021; Dolnicar, 2020; Higham & Miller, 2018). The Glasgow Declaration to decarbonise tourism highlights the urgency with which leading tourism organisations are now approaching the climate-tourism nexus (One Planet, 2021).

For some time, policymakers have questioned the validity of the conventional economic measures such as gross value added and employment as a reflection of success of the tourism sector. Peak bodies of the sector around the world have put forward frameworks to establish sustainable development for the sector as well as economic growth in general. The European Tourism Indicator System (European Commissions, 2016) is the most established and tested system with 43 indicators across four categories, namely destination management, social and cultural impact, economic value, and environmental impact. The use of indicators to monitor tourism impacts has proven to provide an important first step for policymakers to better understand the sector; however, it was also shown that indicators alone will not be sufficient to transform tourism (Font et al., 2021). Thus, while governance arrangements for sustainable tourism more broadly must be reconceptualised, the crucial role of 'measure-to-manage' is widely recognised, especially in the context of greenhouse gas (GHG) emissions (Gössling & Scott, 2018; Whittlesea, Becken, Jago, & Pham, 2019; Becken & Kaur, 2021; One Planet, 2021).

Aiming to capture the 'true value' of the sector, tourism academics have developed a wide range of approaches for decades. Early examples include the Minimal model (Casagrandi & Rinaldi, 2002), a tourism sustainability assessment procedure (Ko, 2005), more recently, managing tourism emissions through optimizing the tourism demand mix (Sun, Lin, & Higham, 2020) and the values-based tourism system

☆ This paper is based on a report previously submitted to the Queensland Government, particularly the Department of Environment and Science and the Department of Innovation and Tourism Industry Development.

* Corresponding author.
E-mail address: t.pham@griffith.edu.au (T. Pham).

https://doi.org/10.1016/j.annale.2022.100062
Received 28 November 2021; Received in revised form 20 June 2022; Accepted 21 June 2022
Available online 27 June 2022
2666-9579/Crown Copyright © 2022 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

(Becken & Kaur, 2021). While these frameworks and models offer pathways to sustainability, they are far from being operational for the reasons that either, all models are purely at the theoretical level without data for implementation thus limiting specific policy recommendations; or, the frameworks only contain representative data at a highly aggregate level such as transport emission as a proxy for tourism emissions. The use of such proxy is neither comprehensive nor effective from a policy perspective, as tourism consumption involves a wide range of other goods and services (Pham, Dwyer, & Spurr, 2009), which all generate emissions.

In addition to academics, public sector agencies have also investigated tourism climate change strategies. One example is the State of Queensland, Australia,[1] which develops the *Queensland Tourism Climate Change Response Plan* as a partnership between the Queensland Government and the Queensland Tourism Industry Council (Becken, Montesalvo, & Whittlesea, 2018). The plan considers physical risks from climate change as well as tourism's contribution to emissions. It includes a range of actions for implementation, with one of the most pressing tasks being the development of an emission inventory for tourism destinations as tourism emissions at the destination level are not available, let alone being well established.

Given the broad guidelines and conventions on the construction of emissions provided by the United Nations (1992) and its the Intergovernmental Panel on Climate Change (IPCC, 2019), most countries follow and adopt for the conventional industries in the national accounts. Quite commonly, countries estimate their annual GHG emissions and convert non-carbon dioxide emissions, such as methane and other GHG to the basis of CO_2-equivalent (CO_2-e) for the reporting and comparison purposes. The Australian Government, for example, produces a very detailed Australian Greenhouse Emissions Information System (Department of the Environment and Energy, 2021). Among just a few countries, New Zealand advances the procedure further and produces an annual tourism greenhouse account alongside the conventional emission inventories, but only at the national level (Stats NZ, 2022). Most countries have no formal or regular estimates of tourism emissions, and to the best of our knowledge, there are no ongoing initiatives that aim at capturing tourism emissions at the destination level. Thus, for destinations seeking to manage their sustainability and carbon risks, this is a serious gap. As such, a systematic approach to estimating tourism emissions, and perhaps some principles, for destinations is inevitably imperative.

This paper puts forward, for consideration, a set of principles to derive tourism emissions for all thirteen tourism destinations within the jurisdiction of Queensland to address to need of the State. In particular, this paper develops a complete and holistic approach to measuring emissions by considering all goods and services associated with visitors' travelling activities at the *destination* level, including international aviation emissions. In essence, the approach integrates three well-established accounting platforms to estimate tourism emissions, namely the regional tourism satellite accounts (TSA), the regional Input-Output (IO) data and the Australian Greenhouse Gas Emission Information System (AGEIS). Emissions are assessed across multi-dimensions: by destination, by broad category, by tourism-related producing industry, by visitor type and also on the per-visitor basis. As such, the contribution of this paper is important in the sense that it provides a comprehensive framework in which emissions are simultaneously consistent within the System of National Accounts (SNA) and the national greenhouse accounts and practical for policy implications – critical features not only from the accounting perspective but also from the policy modelling perspective. The methodology is replicable for other destinations in Australia or in other countries that have similar data sources.

In the following sections, the paper provides a review of existing approaches to measuring tourism emissions. On that basis, it then provides the integrative framework. Finally, results are presented with analysis for policy recommendation.

2. Literature review

Previous studies have shown that tourism emissions can be significant. At the global level, the United Nations World Tourism Organization (UNWTO) has estimated tourism carbon emissions twice. UNWTO first commissioned a study that estimated that tourism contributed approximately 4.95% to global carbon emissions (Scott et al., 2008). Subsequently, UNWTO worked with the World Tourism Organization and International Transport Forum (2019), projecting that by 2030, transport-related emissions from tourism would comprise 5.3% of all anthropogenic carbon emissions. These estimates were obtained using data on tourist activities by transportation mode and tourism type. Using input-output multipliers (including direct and indirect effects), Lenzen et al. (2018) estimated total tourism emissions worldwide to be in the order of 8% of global anthropogenic GHG emissions.

At the country level, Sharp, Grundius, and Heinonen (2016) use an IO-based hybrid life-cycle assessment method to assess the consumption-based carbon footprint of the average tourist to Iceland over the period of 2010–2015. They found that the carbon footprint of an average tourist was about 1.35 t of CO_2-e, within the range of 1.1 to 3.2 t of CO_2-e, depending on the air travelling distances. Meng, Xu, and Hu (2016) estimate the direct and indirect emissions for the Chinese tourism industry. The total direct carbon emissions of the Chinese tourism industry in 2010 were estimated as 208.4 Mt., accounting for 2.45% of total emissions in China. Dwyer, Forsyth, Spurr, and Hoque (2010) estimate the carbon footprint for the Australian tourism sector using both the production-based (supply) and expenditure-based (demand) approaches. They show that in 2003/04 tourism contributed between 3.9 and 5.3% of total GHG emissions in Australia.

Perch-Nielsen, Sesartic, and Stucki (2010) derive the emission intensity (CO_2-e per unit of gross value-added) for the Swiss tourism sector. Results highlighted that the intensity of tourism emission was four times higher than that of the economy-wide average of the Swiss economy, and that air transport generates most of the emissions (80%) and has the highest emission intensity among all goods and services in tourism expenditure. Using a similar approach, Wu and Shi (2011) estimate the energy consumption and carbon emissions of the tourism sector in China. Tourism activities were grouped by transport-related purposes (travel to, from and at the destination) and destination-related purposes (accommodation, food, tourist activities, etc.). A total of 51.34 Mt. of CO_2-e emissions was estimated for the tourism sector, which was only 0.86% of the total emissions in China in 2010. The emissions here seem to be conservative compared to the result from Meng et al. (2016). Focusing on specific tourism industries, Jackson, Kotsovos, and Morissette (2008) estimate total GHG emissions for air transport and food and beverage services in Canada using the IO multipliers. Data for the study were taken from the TSA and the environmental satellite accounts. They found that, for every $1000 of tourism output in 2002, the air transportation industry generated 1.03 t of GHG emissions, significantly higher than just 0.03 t of emissions from the food and beverage sector. For New Zealand, Becken and Patterson (2006) combine the top-down and bottom-up approaches in their study, finding that both generate results of similar magnitude of tourism emissions, not only in total but also at specific sub-sectors such as transport, accommodation and activities. Emission factors for the top-down analysis were sourced from national greenhouse gas statistics, while the bottom-up analysis was informed by earlier data collections directly from tourism businesses. Excluding emissions from international flights, an international visitor to New Zealand was estimated to generate 0.26 t of carbon footprint on average. The emissions from

[1] Australia has six states and two territories, namely New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania, Northern Territory and the Australian Capital Territory.

domestic tourism and international tourism accounted for 5.2% and 1.7%, respectively, of total carbon dioxide emissions in 2007.

At the local level, carbon assessments mostly adopt the bottom-up approach. Most recently, Huang and Tang (2021) gauge the tourism carbon footprint of Heilongjiang Province, China. Findings indicate that total tourism carbon emissions had increased from 5.93 Mt. in 2009 to 21.13 Mt. in 2018, more than three times over the period. Huang and Tang (2016) also estimate that the total of tourism carbon emissions in Hubei Province was about 3.40 Mt. in 2013, quite small compared to that of Heilongjiang Province. Vourdoubas (2019) estimate an amount of 488.77 kg CO_2 emission per visitor to the Island of Crete, the largest and most populous island of Greece. Using a tool based on geographic information systems (GIS), Unger, Abegg, Mailer, and Stampft (2016) estimate the emission resulting from tourism travel to the mountain municipality of Alpbach, Austria. They estimated an amount of 5383 t of emissions, or 142.94 kg CO_2-e per visitor in 2015. Farreny et al. (2011) estimate the carbon emissions for trips to Antarctic was about 5.44 CO_2 tonnes per passenger or 0.49 t per passenger-day. Based on the IO table, Jones and Munday (2007) calculate the direct, indirect and induced waste and GHG emissions due to tourism demand in Wales by combining Wales' TSA data and a pilot environmental satellite account. They found that, in total all visitors to Wales contributed 1.46 million tonnes of GHG emissions through their regional consumption of goods and services. Cheng et al. (2020) build a suburban-scale multi-regional IO table to estimate Airbnb's carbon footprint in Sydney. They estimate that the Airbnb platform and its hosts generate a total impact between 7.29 and 9.39 kg CO_2-e per room night.

In summary, measuring GHG emissions is a complex task due to the heterogenous nature of emitting processes. The task of estimating emissions for tourism is particularly complex and the methodologies to estimate tourism emissions are not directly comparable between studies. Partly, this is due to the different scopes that studies chose, as well as the availability of data. Thus, it is impossible to compare results of tourism emissions across studies. Going forward, it is important to find methodologies that introduce some consistency and, ideally, can be connected to other official statistics including tourism data.

This paper builds on three well-established accounting platforms widely adopted in the national accounts of many countries. The approach is heavily based on the TSA, as such framework contains a full set of commodities consumed by visitors (Pham, Kookana, & Osborne, 2014), designed and advocated by UNWTO (2010) for consistency across countries. Emission results from TSA-based studies are robust (Sun, Cadarso, & Driml, 2020) in the sense that the entire tourism sector is accounted for, and explicitly reflected in a compatible manner with the rest of the industries in an economy; therefore, results offer strong policy applications. However, the TSA framework alone is not enough to ensure the accuracy and nation-wide consistency of the emission data. It is imperative for such calculation to be closely derived in conjunction with the national emissions accounts so that tourism emissions are correctly specified. As such, on the foundation of the regional IO framework, this paper integrates the TSA framework with the emission accounts at the destination level in the State of Queensland, one of the eight states in Australia, so that tourism emissions can be calculated accurately, accounted for entirely, and consistently beyond the selected destinations. It is emphasised that using regional tourism expenditure alone will not guarantee accuracy and consistency in the estimated emissions for the selected destinations and the rest of the country.

3. Methodology

This section first describes the principles of each framework, and then explains how they are integrated to account for tourism emissions of destinations within Queensland, a state of Australia; states and regions are interchangeable in this paper.

3.1. National accounts: The IO table and its multipliers

Although the IO framework is well documented in the literature, it is necessary to revisit it here, as it is the foundation for many emission studies, including this paper. An IO table (Fig. 1) is a snapshot of an economy for one accounting period, either a calendar year or a financial year, depending on the country. The table portrays both the supply side (industry cost structures, including intermediate inputs and value-added components) and the demand side (all final demands, namely household consumption, investment, government consumption and exports).

Primarily, the designated use of an IO table is to reflect the size of an economy and connections of all users in it. The size of the economy can be measured from the supply side (as the sum of P1 to P4), or equivalently from the demand side (the difference between total final demands in Y and P5). The IO table and the relationship of users in the IO table are valuable for measuring and reporting purposes from an accounting perspective. As such, the industry cost structures are useful for estimating emissions associated with the input of each industry (Z matrix).

The linear input-output relationships are often used to trace back the indirect effects on the upstream input as impact analysis through the equation. $X = (I - A)^{-1} * Y$, where A is the input shares of Z in output X. For example, an increase in demand (Y) for vegetables will generate the (first round) direct effect on more labour income and capital income for the vegetable growing industry, and input demand such as fertiliser. This will then induce further upstream (second round) indirect demand for electricity as required by the fertiliser producer. Subsequently, another (third) round of effect could be more demand for gas or coal required by the electricity generator. The indirect effects will loop through multiple rounds in the economy until the additional demand for upstream inputs is completely diminished. The IO multipliers can be used to calculate direct, indirect and induced effects based on the linear relationship of inputs in the production process. The combination of these multipliers is often adopted in economic impact analysis. It is important to note that, among them, only the *direct* effect has the accounting nature that can be linked to, or embedded within, the SNA, while the indirect and induced effects reflect the nature of impact analysis, stimulated by direct effects. Both indirect and induced effects are not part of the SNA reporting framework.

When applying the multiplier technique for impact analysis, it is essential to keep in mind that the estimation of this IO multiplier technique is monotonic in the absence of price elasticity, income elasticity and resource constraints; the method will *overestimate* the impacts due to the lack of substitution and crowding-out effects. As the aim is to construct a *tourism emission account*, it is excessive (therefore not recommended) to include the emissions of the IO indirect and induced effects (using the IO multipliers), as the SNA does not encompass any of these effects.

3.2. Tourism satellite account framework

As tourism is not explicitly recognised in the SNA, this gives rise to the creation of the satellite accounts that 'allow an expansion of the national accounts for selected areas of interest while maintaining the concepts and structures of the core accounts' (Australian Bureau of Statistics, 2019). The TSA framework (UNWTO, 2010) classifies tourism demands into direct and indirect groups. The direct group refers to the goods and services that have direct physical contact between visitors and producers. In contrast, when such direct contact does not exist, goods and services are classified into the indirect group. Only output of the direct constituents is counted toward tourism output. While output of the indirect ones is excluded, the retail margins where shopfront and retail staff are required to serve visitors with these indirect goods are included in the tourism output. Expenditure on petrol or diesel is a good example. They are produced by the refineries which do not interact with final users such as tourists. Therefore, in the TSA, values of fuel are not considered in tourism output. However, the petrol stations sell fuel on

	Industry J1 J2 J3 … Jn	Final Demands	Total Sales
Commodity C1 C2 C3 … Cm	Z	Y	X
	T1: Total Intermediate use		
	Value Added P1: Compensation of employees (COE) P2: Gross operating surplus & mixed income P3: Net taxes on production P4: Net taxes on products P5: Imports		
	Total Output X		

Fig. 1. A stylised IO table.

behalf of the refineries and have a direct contact with tourists, thus only the (fuel) retail component is counted as part of the tourism output. The best way is to think of fuel or any other manufacturing goods as intermediate inputs in the cost structure of the tourism industry, thus not included as gross value-added (GVA) of the sector (tourism contribution to the economy). Total tourism output is the sum of all direct constituents, which is so much less than total tourism expenditure; this is the essence of the production-based approach in some previous emission studies. Thus, the production-based approach results in a significant lower estimate of tourism emissions.

3.3. Carbon emissions account framework

The emission accounts have numerous definitions in the framework, among which, direct and indirect emissions are clearly differentiated. However, these terms have different meanings from the other two frameworks. The direct and indirect concept of the emission accounting framework bears no reference to the input stream, nor direct physical contact between producers and visitors. Rather, it reflects the causal relationship between an activity and the emission. In a simplest summary, it is conceptualised as below.

> ***Direct emissions** are produced from sources within the boundary of an organisation and as a result of that organisation's activity.*
>
> ***Indirect emissions** are emissions generated in the wider economy as a consequence of an organisation's activities (particularly from its demand for goods and services), but which are physically produced by the activities of another organisation.*

(Department of the Environment and Energy, 2021*, p. 6*)

The above-mentioned example of fuel consumed by self-drive visitors illustrates direct emissions. The *boundary* of emissions here is not a particular location as other production lines, it is the entire trip of the visitors. On the other hand, indirect emissions stem from, for example, the electricity used by restaurants or hotels to run air conditioners and light to serve visitors. These emissions occur at the point of electricity generation, not at the restaurants and hotels where visitors are served. Distinguishing direct and indirect emissions is necessary in the conventional logic to identify emissions and emitters *for accountability* among economic activities, where the boundary of production and economic activities are well defined. Separating direct from indirect emissions in tourism seems to divert all emissions, and accountability, away from tourism to the manufacturing sector, as output of tourism is the experience for visitors. It is hard to conceptualise how "visitors' experience" can generate emissions! To better reflect tourism emissions correctly for the accountability purpose, results for direct and indirect emissions must be consolidated.

3.4. The integrated framework

In the following, the key elements of the framework adopted in this study are illustrated using an example of a multi-day trip for a self-drive and self-catering group of visitors. The visitors spend money on petrol, pay rent for an apartment and buy meat and vegetables for cooking their meals.

For the apartment, the *producer* and visitors have direct contact, thus the total rent is included as direct tourism output in the TSA framework. On the other hand, the fuel cost, say $100, incurred to the visitors is not entirely included in the tourism output. Rather, only the running cost of the petrol station, say $20, is counted toward tourism output while the fuel cost itself $80 is excluded, because it is treated as input cost to retailers in the TSA. The split of direct and indirect tourism output follows the accounting framework in the SNA, where inputs and value-added components are clearly identifiable with specific roles in the production process. The structure of tourism *production* is more challenging, because symbolically 'tourism' is an intermediary gathering of goods and services and providing them to visitors; thus, there is no usual dichotomy between inputs and value-added components. They need to be *extracted* from the visitors' consumption bundle. Essentially, the TSA framework represents a tool that contextualises inputs and value-added components for tourism. The direct tourism constituents play the role of the 'value-added' block while the indirect ones are deemed as intermediate inputs. Once classified, the value-added amounts from the producing industries in the direct group are added up to generate the overall tourism value-added or referred to as tourism economic 'contribution' from the accounting perspective. The indirect elements are taken out of this calculation due to the nature of intermediate inputs. The national account measures the contribution of a producing industry to the economy only by the value-added components, consistently across all industries in the economy, to avoid double counting. It is necessary to apply such principle to tourism, as defined in the TSA framework. However, the key point here is that within the conventional industries in the SNA framework, the value-added components do not generate emissions; it is the intermediate inputs and the domestic production process that generate emissions. Thus, as in the principle, for an accurate

(and informative) tourism footprint calculation, it is important to ensure inclusion of emissions from all indirect constituents – inputs of the tourism sector – such as those generated from manufacturing of goods.

Furthermore, if counting on direct tourism constituents only, the emissions from agricultural products such as meat or vegetables that the visitors purchase for cooking in the above example will also be missed out (and similarly, emissions from restaurant foods for many other visitors) while these are real "inputs" to the visitors' trip, but they are masked under indirect tourism constituents and removed from the tourism consumption bundle. This warrants inclusion of *tourism input emissions* in the calculation. However, the question is to what extent and how far these upstream inputs should be incorporated to correctly account for tourism emissions. Here, we adopt an essential principle that any *immediate* goods that visitors consume, or demand, are considered as intermediate inputs to tourism, and subsequently derive the input emissions for them. The inclusion of all immediate inputs consumed by visitors, such as meat, vegetables and electricity via hotels/restaurants or meat purchased directly by visitors in the example above, is fully justifiable under the 'indirect emission' rationale, as practically, they are the intermediate inputs in the tourism "production". Any further steps beyond the immediate round using the IO multipliers, such as electricity used by the fertiliser producers who supply fertiliser to agriculture to grow fruits and vegetables for tourism, would seem far-fetched. Notionally, the approach of using IO multipliers measures the full chain of impacts, adding more values to the contribution (account) of a sector in an economy, i.e. double counting. As the aim here is to derive tourism emissions in the form of an 'account' that is compatible not only with the national greenhouse accounts but also with the SNAs, using an impact analysis tool such as the IO multiplier approach would not be appropriate.

In short, the approach first includes both direct and indirect measures of the TSA framework to derive an emissions account of the full tourism consumption set. The process is further extended to include emissions from inputs (mainly agricultural products and electricity used in hotels and restaurants), referred to as input emissions. All up, the approach covers most of the "direct and indirect" elements of the emission account, which are all aggregated into the total emissions in this paper, as the separation between direct and indirect emissions according to the emission accounts framework seems to be unnecessary for tourism. Thus far, the approach has not captured international aviation emissions. One reason is that the official tourism expenditure data (Tourism Research Australia, 2019) does not include international airfares at the regional level. There is also a further complication in that national climate commitments do not include emissions from the so-called bunker fuels such as those used for international aviation (Faber et al., 2020). Instead, international aviation emissions are addressed through a global framework developed by the International Civil Aviation Organisation, but global data are not available to the public. In order to account for all emissions related to tourism consumption from the TSA entirely, it is important that international aviation emissions are included to destinations where visitors travel through during their trips.

4. Procedure and data

Fig. 2 summarises the procedure and data sources used in this study. The sources are cited in parenthesis underneath the data set in the figure and all data are for 2016/17.

4.1. Australia greenhouse gas emission information system

Emission data from the Department of the Environment and Energy (DEE) cover many industries as well as the household sector for all states and territories, as well as the national aggregates. However, data are not available for all emitting agents at the state level due to confidentiality. Thus, using the available state data and the national totals by emitting agent, a procedure was applied to disaggregate the national data to fill in those concealed cells at the state level. After filling in missing values for all regions, emissions are converted into emission rates per unit of output for all industries, or *emission coefficients*, across all states and territories. Although this study is interested in tourism destinations in Queensland, it is important to work on all states and territories to ensure the adding-up condition of emission data between states and the whole Australia. The emission coefficients for the Queensland level were then applied to industries in tourism destinations within the state.

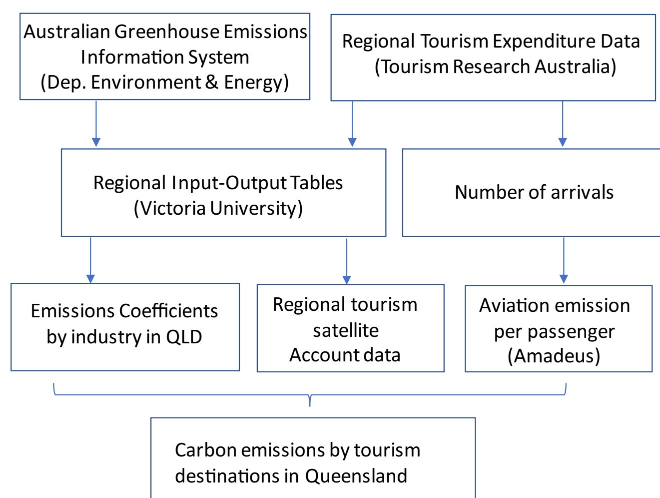


Fig. 2. An overview of tourism emissions framework for destinations in Queensland.

4.2. Regional TSA

The calculation of emissions for tourism destinations in this study relies strongly on the regional TSA data. This paper adopts the approach developed by Pham et al. (2009) to derive the required regional TSA for destinations of Queensland, which covers explicitly domestic overnight (including both inter-regional and intra-regional tourism flows), day-trip and international tourism markets. At first, the process was to convert regional tourism expenditure to regional tourism consumption that considers the imputed tourism expenditure not included in the tourism expenditure survey, for example food and drink provided to visitors when they visit friends and relatives. Then, essentially, the TSA process is to decompose tourism consumption at the purchasers' prices into tourism consumption at basic prices, commodity taxes, imports and margins. The tourism consumption at basic prices is equivalent to tourism output. This task was implemented using the regional IO database (Horridge, Madden, & Wittwer, 2005) that captures all thirteen tourism destinations of Queensland. By applying the emission coefficients to the regional tourism output, tourism emissions are derived.

4.3. Aviation emissions

Emissions for international air transport were calculated using data from the Amadeus IT Group (Becken & Shuker, 2018; Global Sustainable Tourism Dashboard, 2019). The monthly emission data for all itineraries arriving in Queensland were used to calculate average rates of emissions per passenger for each country of origin to all airports in Australia.

Regional tourism expenditure data from TRA provide information on the number of international visitors by country of origin. The data also show the arrival airports in all states in Australia and the number of nights visitors spent at each subsequent destinations in Australia. By combining the emission rates and the number of visitors from individual countries, total emissions of international visitors by country of origin were estimated. Then, using the visitor night shares, anchored at the

arrival airports, total aviation emissions were then allocated to the individual destinations where the visitors went. In this way, international aviation emissions were attributed to all destinations/regions in Australia, depending on the significance of each destination in tourists' itineraries. This approach avoids allocating international aviation emissions entirely to the gateway cities where international airports are located; it represents a more equitable approach to destinations' accountability.

The whole procedure above generates five different categories of emissions in this study. All of these are expressed in CO_2-e.

1. Emissions from the goods and services produced by local industries (combined TSA direct and indirect, referred to as **Tourism Output**, including domestic air transport)
2. Emission from imported goods
3. Emissions from fuel consumption by self-drive visitors
4. Emissions from immediate inputs in visitors' consumption bundle, mainly agricultural products and electricity (*tourism input emissions* or **Tourism Inputs** for short)
5. Emissions from international flights.

5. Results

5.1. Tourism emissions by broad category

The tourism sector in Queensland is estimated to generate a total of 11.6 million tonnes (Mt) of CO_2-e for 2016/17 (Table 1 and Fig. 3). The top three popular destinations in the state – Brisbane, the Gold Coast and Tropical North Queensland (Cairns) – are estimated to generate the largest amounts of emissions: 4 Mt. (34%), 1.9 Mt. (16.5%) and 1.6 Mt. (14%) respectively, followed by the Sunshine Coast with nearly 1.2 Mt. (10%). Emissions from all other destinations are relatively at much lower levels. Fig. 3 presents the shares of carbon emission across all tourism destinations.

Among all five broad categories, emissions from *Tourism Inputs* are nearly the same as the level of emissions generated from all other goods and services produced by domestic industries for visitors (Tourism Output). The total of emissions from these two groups contributes slightly more than 60% of the total emissions in the state. The rest is made up of nearly equal proportions of international aviation (17%) and fuel for privately used vehicles (19%). Emissions from imported goods are not so significant overall (Fig. 4).

5.2. Tourism emissions by tourism-related producing sector

Table 2 rearranges tourism emissions into a typical consumption-based profile of total emissions.

- Emissions from fuel consumption are now embedded in road transport.
- Emissions from domestic air transport and international air transport are combined in air transport.
- Input emissions from meat and vegetables are now allocated back to the restaurant sector and “other food and drink” (for “self-catering” meals).
- Input emissions from electricity generation are also allocated back to tourism-related using industries such as hotels and restaurants.

Table 3 and Fig. 5 present the emissions in Table 2 on the basis of the percentage shares. Overall, air transport and road transport are the two sectors contributing the most to total tourism emissions – 38% and 24% respectively, more than emissions from all other sectors adding together. Both the restaurant and “other food drink” sectors have higher emission shares than the hotel sector. This is because agricultural products carry high levels of embedded emissions (high emission coefficients).

Relatively, emission shares for road transport are much higher in Outback Queensland and Southern Queensland Country than in other destinations, implying that road transport is the main means to get to these two destinations. Indeed, TRA data indicates that most trips to these two destinations are self-drive, as evidenced for Western Downs[2] (Pham & Ngo, 2019) that the fuel share in total consumption for visitors to this region was very high (26.8%) compared with the national average (9%). The beauty of nature in these destinations offers attractive and extensive land travel experiences, giving rise to this high share of road transport emission. In contrast, air-transport is a more common means for visitors to reach Brisbane, Tropical North Queensland, Townsville and the Whitsunday, consequently aviation emissions are high for these destinations: 47%, 45%, 41% and 40% respectively. The emissions data reveal the importance of understanding the context of each destination, its distribution of attractions and its connectedness to wider transport networks and itineraries.

Tourism destinations in Queensland tend to form two groups with distinct expenditure patterns in terms of food consumption. The group of the Fraser Coast, the Gold Coast, the Sunshine Coast, Whitsunday and Capricorn generally has high shares of emissions for food consumption, either from meals served in the restaurants or self-catering. Among these regions, the Gold Coast, Whitsunday and the Sunshine Coast are well above the state average shares. These are probably tourism destinations attracting visitors seeking higher-end experience in their travelling, thus dining out in restaurants is a necessary part of their trips (which draw on the inputs of meat and dairy products – with high embedded carbon emissions content). In contrast, Outback Queensland, Townsville, Gladstone and even Brisbane are regions with low proportions of emissions from food. Although this is hard to explain in the case of Brisbane, the other three regions appear to offer similar travel experiences toward natural attractions, so food might not be a major part of the experience that visitors are seeking.

5.3. Tourism emissions by visitor type

Table 4 presents tourism emissions broadly by type of visitors: domestic overnight visitors, domestic day visitors (day-trip) and international visitors. In comparison, domestic overnight visitors contribute the largest share of 53.8% in total emissions in Queensland, followed by international (or inbound) visitors (31.8%) and day-trip visitors (14.4%).

Relatively, domestic overnight visitors generate the largest proportions of emissions (around 75%) in Mackay, Outback Queensland and the Capricorn Coast compared to the same type of visitors in all other regions. Also in the relative term, international visitors generate larger emission shares (at least 37%) in Brisbane, the Gold Coast, Tropical North Queensland (Cairns) and the Whitsunday than in other regions. For the day-trip market, Southern Queensland Country, the Fraser Coast and Bundaberg have larger emission shares than most other destinations. While Southern Queensland Country could attract visitors from within surrounding areas, day-trip visitors to the Fraser Coast are more likely to be from organised day-tours for visitors staying on the Sunshine Coast. This explains a relatively high share of road transport emissions (35%) for the Fraser Coast, shown in Table 3 earlier.

Finally, emissions are assessed on a per visitor basis (Table 5). Results show that on a state-wide average basis, a typical international visitor generates three times more than an average domestic overnight visitor. The differences in emissions vary across tourism destinations, with the largest gaps being observed in Brisbane, Bundaberg and Southern Queensland Country: from 4.7 to 6.6 times larger. These differences can be due to many factors, including the visitor mix of country of origin to the destinations – mainly from New Zealand, the United Kingdom, the United States, Canada and Germany, involving mainly long-haul flights.

[2] One of the local areas within Southern Queensland Country.

Table 1
Tourism emissions of destinations by broad category, 2016/17.

	Tourism output	Fuel	Imports	Tourism inputs	International aviation	Total
				million tonnes		
Brisbane	1.37	0.58	0.09	1.06	0.89	3.99
Bundaberg	0.03	0.06	0.01	0.06	0.04	0.20
Southern Queensland Country	0.12	0.22	0.03	0.16	0.04	0.56
Fraser Coast	0.04	0.07	0.01	0.07	0.03	0.22
Gold Coast	0.53	0.27	0.05	0.70	0.37	1.91
Mackay	0.08	0.07	0.01	0.06	0.02	0.23
Townsville	0.20	0.12	0.02	0.13	0.06	0.53
Outback Queensland	0.10	0.20	0.02	0.09	0.02	0.44
Sunshine Coast	0.26	0.27	0.04	0.45	0.13	1.15
Tropical North Queensland	0.54	0.18	0.03	0.51	0.33	1.58
Whitsunday	0.11	0.03	0.01	0.12	0.06	0.33
Capricorn	0.09	0.10	0.01	0.10	0.02	0.32
Gladstone	0.04	0.05	0.01	0.04	0.03	0.15
Queensland	**3.51**	**2.22**	**0.33**	**3.54**	**2.02**	**11.61**

Source: authors' calculation.

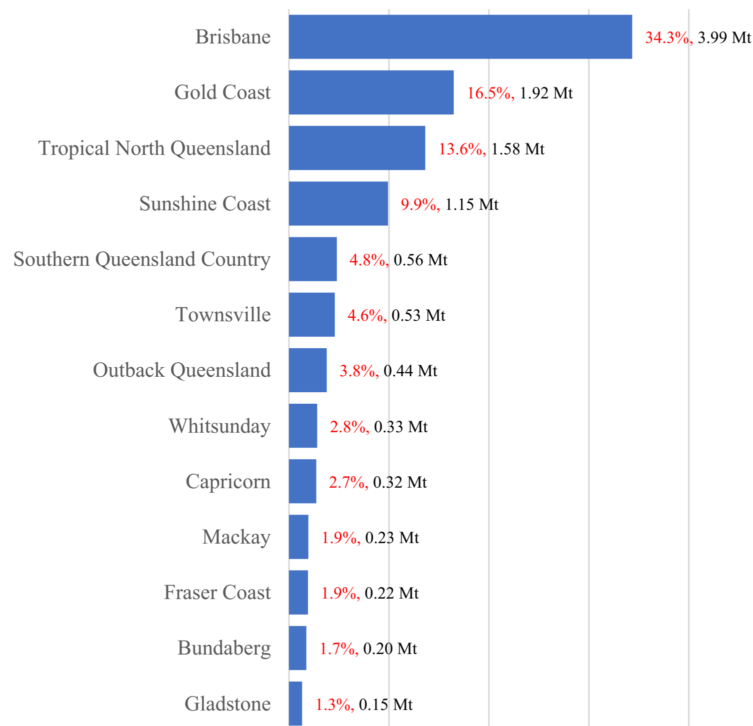


Fig. 3. Regional emission shares in Queensland total, 2016/17.

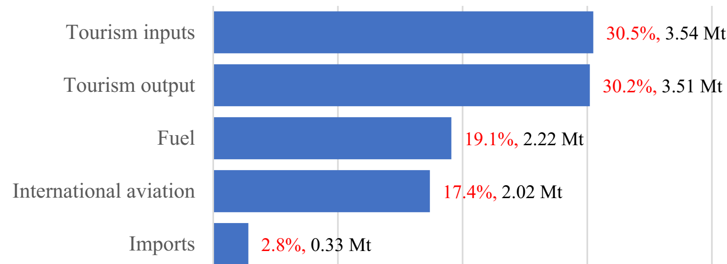


Fig. 4. Tourism emission profile for Queensland, 2016/17.

Table 2
Emissions by tourism-producing sector (Mt), 2016/17.

	Air	Road	Other transport	Accom	Restaurant	Other food drink	Shopping	Others	Total
					million tonnes				
Brisbane	1.89	0.84	0.02	0.14	0.27	0.39	0.13	0.32	3.99
Bundaberg	0.06	0.06	0.00	0.01	0.02	0.03	0.00	0.02	0.20
Southern Queensland Country	0.11	0.23	0.01	0.02	0.05	0.06	0.02	0.07	0.56
Fraser Coast	0.05	0.08	0.00	0.01	0.02	0.03	0.01	0.02	0.22
Gold Coast	0.69	0.37	0.01	0.13	0.22	0.26	0.05	0.18	1.91
Mackay	0.07	0.07	0.00	0.01	0.02	0.02	0.00	0.02	0.23
Townsville	0.22	0.15	0.01	0.02	0.03	0.04	0.01	0.05	0.53
Outback Queensland	0.09	0.21	0.01	0.01	0.03	0.03	0.00	0.05	0.44
Sunshine Coast	0.28	0.32	0.01	0.07	0.15	0.18	0.02	0.12	1.15
Tropical North Queensland	0.72	0.28	0.01	0.09	0.13	0.20	0.03	0.12	1.58
Whitsunday	0.13	0.06	0.00	0.02	0.04	0.04	0.00	0.03	0.33
Capricorn	0.08	0.11	0.00	0.01	0.03	0.03	0.01	0.04	0.32
Gladstone	0.05	0.05	0.00	0.01	0.01	0.01	0.00	0.02	0.15
Queensland	**4.45**	**2.84**	**0.09**	**0.55**	**1.01**	**1.33**	**0.30**	**1.06**	**11.61**

Source: authors' calculation.

Table 3
Tourism emission shares by tourism-producing sector (%), 2016/17.

	Air	Road	Other transport	Accom	Restaurant	Other food drink	Shopping	Others	Total
					Percent				
Brisbane	47.32	21.05	0.513	3.49	6.66	9.75	3.27	7.95	100
Bundaberg	29.31	32.04	0.970	4.52	8.41	12.54	1.84	10.36	100
Southern Queensland Country	19.70	41.39	0.990	3.38	8.28	10.50	2.92	12.85	100
Fraser Coast	23.83	35.41	1.198	4.23	10.40	11.40	2.32	11.21	100
Gold Coast	36.17	19.53	0.666	6.64	11.44	13.42	2.87	9.26	100
Mackay	33.18	32.49	0.975	5.18	7.37	9.14	1.85	9.82	100
Townsville	41.10	28.04	1.046	3.32	6.49	8.39	2.08	9.53	100
Outback Queensland	21.14	48.68	1.188	2.32	5.88	7.84	0.92	12.04	100
Sunshine Coast	24.41	27.49	0.899	6.42	12.66	15.94	2.09	10.09	100
Tropical North Queensland	45.43	17.54	0.890	5.52	8.25	12.87	1.86	7.63	100
Whitsunday	40.17	18.47	0.878	7.47	11.53	12.54	1.22	7.73	100
Capricorn	23.92	34.72	1.208	4.02	10.32	10.02	2.91	12.88	100
Gladstone	32.44	35.71	0.725	4.50	7.30	8.46	0.96	9.91	100
Queensland	**38.28**	**24.48**	**0.76**	**4.72**	**8.66**	**11.43**	**2.57**	**9.09**	**100.00**

Source: authors' calculation.

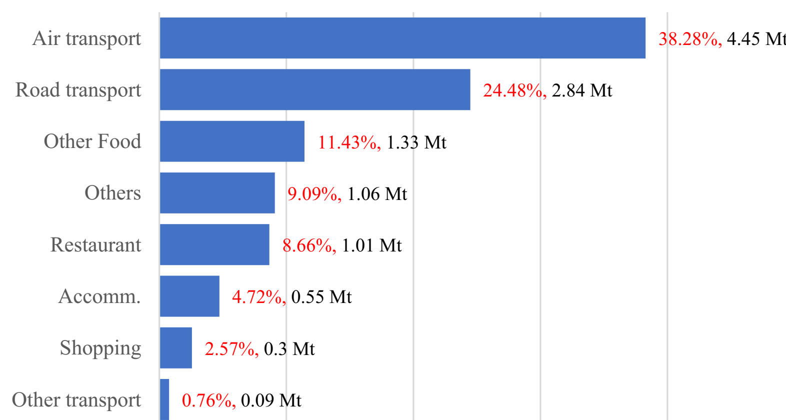


Fig. 5. Emission shares by tourism-producing sectors in Queensland (%), 2016/17.

6. Discussion

6.1. Comparison

The nature of emission measures here needs to be kept in mind when comparing results with other studies. In the first instance, while this study relies heavily on the direct coefficients of the IO table, emissions in this study are not further estimated using the IO multipliers, as the multiplier approach will mix 'impact' results with the 'contribution' nature of the national accounts.

This research presents comprehensive measures of emissions, encompassing all necessary activities and experiences for tourism to occur. The framework presented here resembles the *expenditure* approach, as it includes emissions from all sources, including tourism inputs, fuel consumption for self-drive visitors, imported goods and

Table 4
Emissions by visitor type (Mt), 2016/17.

	Domestic overnight	Day	Inbound	Total	Domestic Overnight	Day	Inbound	Total
	million tonnes				*shares (percent)*			
Brisbane	1.8143	0.583	1.590	3.99	45.5	14.6	39.9	100.0
Bundaberg	0.113	0.040	0.049	0.20	55.8	19.9	24.3	100.0
Southern Queensland Country	0.341	0.159	0.057	0.56	61.2	28.5	10.3	100.0
Fraser Coast	0.129	0.051	0.041	0.22	58.3	23.1	18.6	100.0
Gold Coast	0.993	0.221	0.701	1.91	51.8	11.6	36.6	100.0
Mackay	0.170	0.033	0.022	0.23	75.6	14.5	9.9	100.0
Townsville	0.355	0.084	0.094	0.53	66.6	15.7	17.7	100.0
Outback Queensland	0.340	0.078	0.022	0.44	77.2	17.8	5.0	100.0
Sunshine Coast	0.738	0.213	0.199	1.15	64.1	18.5	17.3	100.0
Tropical North Queensland	0.748	0.109	0.727	1.58	47.2	6.9	45.9	100.0
Whitsundays	0.177	0.016	0.136	0.33	53.8	4.8	41.4	100.0
Capricorn	0.236	0.057	0.025	0.32	74.3	17.9	7.8	100.0
Gladstone	0.093	0.026	0.035	0.15	60.4	16.8	22.8	100.0
Queensland	**6.245**	**1.671**	**3.699**	**11.61**	**53.8**	**14.4**	**31.8**	**100.0**

Source: authors' calculation.

Table 5
Emissions per visitor (tonnes), 2016/17.

	Domestic overnight	Day	Inbound
	tonnes per visitor		
Brisbane	0.268	0.039	1.261
Bundaberg	0.205	0.061	1.201
Southern Queensland Country	0.184	0.047	1.219
Fraser Coast	0.229	0.064	0.290
Gold Coast	0.282	0.036	0.693
Mackay	0.196	0.048	0.507
Townsville	0.328	0.046	0.735
Outback Queensland	0.373	0.130	0.753
Sunshine Coast	0.217	0.035	0.693
Tropical North Queensland	0.418	0.048	0.838
Whitsunday	0.347	0.051	0.590
Capricorn	0.247	0.040	0.351
Gladstone	0.204	0.060	0.611
Queensland	**0.269**	**0.042**	**0.877**

Source: authors' calculation.

international air transport.[3] However, it is more comprehensive than the expenditure approach as it also comprises the imputed consumption not directly incurred by visitors (not recorded in the expenditure survey). This is important for considering tourism policies related to economic contributions versus carbon impacts of the sector (e.g. Perch-Nielsen et al., 2010).

Apart from the methodology, each country has different infrastructure and different types of tourism experience, so the structure of the associated emissions would not be directly comparable across countries. Long-haul flights are inevitable for international visitors when Australia is far away from the rest of the world while road transport might be sufficient for international visitors among the European countries. Tourism destinations within Australia have different climates, landscapes and cultural characteristics, offering diverse experiences. Visitors from overseas often try to visit as many places as possible during their visits to maximise their experiences. Tourism destinations in Australia are scattered over a large area of the country, inherently leading to itineraries marked by long travel distances, both for domestic and international visitors. The geography is not the same in other countries, where closer concentration of attractions results in short travel distances, including those that can be served by public transport. Even within Queensland, substantial differences exist among destinations. Care must be taken when comparing results.

In total, Queensland was estimated to produce 161.2 Mt. of CO_2-e in 2016/17 (Department of the Environment and Energy, 2021). This paper estimates a total of 11.6 Mt. of CO_2-e for the tourism sector for the same year, equivalent to about 7.2% of Queensland's total. This includes emissions associated with imported goods and international aviation, which are not counted in Queensland's total emissions. This result is within the range of compatible tourism studies, including a contribution of 11.2% found by Dwyer et al. (2010) for Australia nationally and 6% noted in Becken and Patterson (2006) for New Zealand.

6.2. Policy implications

Tourism policy development needs to consider emissions on both total and per capita bases, as they will provide a more comprehensive ground for mitigating tourism's climate change effects. More specifically, while domestic tourism accounts for a large amount of emissions in Queensland, the carbon footprint on the per person basis for international visitor is much higher. Thus, additional promotion and increases in international visitations will lead to much faster rates of increases in emissions from the international market, compared to the case of the domestic market. There is an increasing global demand to address tourism's carbon footprint, and it is also in the interest of Australia to promote a low-carbon development path (Becken et al., 2018). The inherent relationship between emissions and tourism growth requires a proper modelling framework to examine scenarios that could lead to reductions in emissions while minimising adverse impacts on tourism growth. This could be done through a combined framework in which the tourism emissions are embedded in a tourism CGE model, so that changes in tourism demand and resultant emissions can simultaneously be captured in what-if scenarios of policy changes such as carbon tax (Meng, Pham, Dwyer, & Grant, 2020; Zhang & Zhang, 2018).

Given the geographic position of Australia, emissions from international aviation seem to be inevitable with current technologies, although there are considerable differences between different markets and airlines. Similarly, the natural configuration of domestic destinations across Australia seems to induce large emissions from internal air transportation and road transport including self-drive activities. Addressing tourism emissions, therefore, needs to be part of a wider national transport decarbonisation strategy, requiring better policy integration between tourism, environment and transport agencies (Becken, Whittlesea, Loehr, & Scott, 2020). For example, the Queensland Government is investing in the electrification of land transport, as such tourism could become an active player in the adoption of these new technologies (e.g. rental vehicle companies). While train travel presents some challenges in Australia, there could be opportunities to transform some air travel toward lower carbon options. Electric aviation is emerging as a possible option, but more likely limiting to short distances

[3] Emissions from imported goods and international aviation are not included in the state total emissions reported by the Department of the Environment and Energy.

in the near future. Biofuels and other alternative fuels (e.g. synthetic) are being explored, but at present their scale is small and for some feedstocks there are considerable sustainability challenges (Faber et al., 2020). If carbon offsets are a policy option, then the carbon footprint for tourism developed here play a very important role, to provide an explicit level of offsets required to compensate for tourism emissions. However, there is increasing recognition that carbon compensation is only a temporary measure (One Planet, 2021) and this should be considered in any policy response.

The examination of different types of visitors and their respective carbon footprints is highly relevant to tourism organisations, especially when developing new marketing campaigns and developing air links. A proactive approach to mitigating emissions while retaining economic contribution will help reduce emissions and manage carbon exposure (Becken & Shuker, 2018). Using the tourism emission data developed in this paper, metrics such as the eco-efficiency (e.g. $/$CO_2$) could inform future market compositions and help design visitor experiences and supply systems in ways that enable more environmentally friendly behaviours (Dolnicar, 2020). At the individual level, further analysis in the pattern of expenditure per visitor for each visitor type could reveal the cause of emissions in a detailed level for policy development. This could be followed up and complemented by surveys on visitor behaviour with special reference to emission objectives so that both the carbon accounts and the survey results can provide a deep understanding of strategies to reduce tourism emissions. This is even more important given that an increasing number of visitors feel conscious of their carbon footprint, to the extent of experiencing 'flight shame'. Offering low-carbon alternatives may become an important ingredient of the Queensland tourism portfolio.

7. Concluding remarks

The lack of tourism emission data severely limits the development of governments' decarbonisation policies, specially at the destination level. This paper presents a framework that incorporates all aspects so that the carbon footprint of tourism activities can be represented comprehensively. Importantly, the framework captures the multifaceted nature of tourism emissions, namely by destination, by broad category, by tourism-related producing industry, by visitor type and also on the per visitor basis. The framework ensures the consistency across different well-established accounting platforms: the TSA, the National Greenhouse Accounts and the SNAs. As such, emission data from this paper will provide a solid foundation and valuable information from different angles that can enable government departments, academics, and the tourism industry to develop robust policies that can promote growth of the sector and mitigate adverse impacts on the environment at the same time.

When applied to destinations in Queensland, Australia, the results reveal rich information, highlighting that some destinations contribute disproportionally to the overall footprint, due to the visitor volume, or the nature of activities and the mix of visitors. Clearly, carbon risk is higher for those destinations that attract more international visitors; however, there is also considerable exposure for remote destinations dependent on domestic self-drive markets.

Undoubtedly, curbing tourism emissions means constraining the growth of the sector, at least when measured on a volume metric rather than value-based metric. Policies aimed at decarbonising tourism may still consider value-based metrics but on the basis to maximise eco-efficiency. Regardless of seeking to optimise economic output versus climate mitigation, it is important that each destination and each visitor type needs to be addressed with tailored mitigation options. In many cases, these will involve cross-governmental collaboration and policy integration, as well as public-private partnerships that support innovation toward low-carbon visitor experiences. The construction of an emission accounts is not the end; rather, it serves as a starting point for a more comprehensive (policy) modelling process to be explored, and this should be continued with regular updates of the tourism emissions account to monitor progress.

Acknowledgement

We would like to thank the Department of Environment and Science and the Department of Innovation and Tourism Industry Development for the financial support to undertake this research (Grant ID: 201900433). Comments and feedback from staff of the two Departments are greatly appreciated.

We would also like to thank staff at Tourism Research Australia of AusTrade for their kind advice and provision of data throughout the whole project. Last but not least, thanks are due to Dr. Tra My Ngo and Dr. Thuc Pham for their excellent assistance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.annale.2022.100062.

References

Australian Bureau of Statistics. (2019). Quality declaration – Summary. In *Australian National Accounts: Tourism satellite accounts* (pp. 2017–2018). Canberra: ABS.

Becken, S., & Kaur, J. (2021). Anchoring 'tourism value' within a regenerative tourism paradigm – A government perspective. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2021.1990305

Becken, S., Montesalvo, N., & Whittlesea, E. (2018). *Building a resilient tourism industry: Queensland tourism climate change response plan*. Brisbane: QTIC. Available at http://www.qtic.com.au.

Becken, S., & Patterson, M. (2006). Measuring national greenhouse gas emissions from tourism as an important component towards sustainable tourism development. *Journal of Sustainable Tourism, 14*(4), 323–338.

Becken, S., & Shuker, J. (2018). A framework to help destinations manage carbon risk from aviation emissions. *Tourism Management, 71*, 294–304.

Becken, S., Whittlesea, E., Loehr, J., & Scott, D. (2020). Tourism and climate change: Evaluating the extent of policy integration. *Journal of Sustainable Tourism, 28*(10), 1603–1624. https://doi.org/10.1080/09669582.2020.1745217

Casagrandi, R., & Rinaldi, S. (2002). A theoretical approach to tourism sustainability. *Conversation Ecology, 6*(1), 13. http://www.consecol.org/vol6/iss1/art13.

Cheng, M., Chen, G., Wiedmann, T., Hadjikakou, M., Xu, L., & Wang, Y. (2020). The sharing economy and sustainability – assessing Airbnb's direct, indirect and induced carbon footprint in Sydney. *Journal of Sustainable Tourism, 28*(8), 1083–1099. https://doi.org/10.1080/09669582.2020.1720698

Department of the Environment and Energy. (2021). *National Greenhouse Accounts factors – Australian National Greenhouse Accounts*. Canberra: Australian Government.

Dolnicar, S. (2020). Designing for more environmentally friendly tourism. *Annals of Tourism Research, 84*, Article 102933.

Dwyer, L., Forsyth, P., Spurr, R., & Hoque, S. (2010). Estimating the carbon footprint of Australian tourism. *Journal of Sustainable Tourism, 18*(3), 355–376.

European Commissions. (2016). The European Tourism Indicator System – ETIS toolkit for sustainable destination management. https://ec.europa.eu/docsroom/documents/21749.

Faber, J., Lee, D. S., Becken, S., Corbett, J. J., Cumpsty, N., Fleming, G., … Smith, T. (2020). *International aviation and shipping. Chapter 5. United Nations Environment Programme (2020). Emissions Gap Report 2020* (Nairobi).

Farreny, R., Oliver-Sola, J., Lamers, M., Amelung, B., Xavier, G., Rieradevall, J., … Benayas, J. (2011). Carbon dioxide emissions of Antarctic tourism. *Antarctic Science, 23*(6), 556–566. https://doi.org/10.1017/S0954102011000435

Font, X., Torres-Delgado, A., Crabolu, G., Palomo Martinez, J., Kantenbacher, J., & Miller, G. (2021). The impact of sustainable tourism indicators on destination competitiveness: The European tourism Indicator system. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2021.1910281

Global Sustainable Tourism Dashboard. (2019). Data available from. http://www.tourismdashboard.org.

Gössling, S., & Scott, D. (2018). The decarbonisation impasse: Global tourism leaders' views on climate change mitigation. *Journal of Sustainable Tourism, 26*(12), 2071–2086. https://doi.org/10.1080/09669582.2018.1529770

Higham, J., & Miller, G. (2018). Transforming societies and transforming tourism: Sustainable tourism in times of change. *Journal of Sustainable Tourism, 26*(1), 1–8. https://doi.org/10.1080/09669582.2018.1407519

Horridge, M., Madden, J., & Wittwer, G. (2005). The impacts of 2002-03 drought on Australia. *Journal of Policy Modelling, 27*, 285–308.

Huang, H., & Tang, L. (2016). Calculation analysis of tourism carbon emissions amount—A case study. *Chemical Engineering Transactions, 51*, 1165–1170. https://doi.org/10.3303/CET1651195

Huang, T., & Tang, Z. (2021). Estimation of tourism carbon footprint and carbon capacity. *International Journal of Low Carbon Technologies, 16*, 1040–1046.

IPCC. (2019). Refinement to the 2006 IPCC guidelines for National Greenhouse gas Inventories. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

Jackson, C., Kotsovos, D., & Morissette, C. (2008). Linking the Canadian tourism satellite account and the Canadian system of environmental and resource accounts to measure the environmental impact of tourism in Canada: An exploratory study for two pilot industries. In *Paper presented at the 9th International Forum on Tourism Statistics, Paris, 19–21 November*.

Jones, C., & Munday, M. (2007). Exploring the environmental consequences of tourism: A satellite account approach. *Journal of Travel Research, 46*(2), 164–172.

Ko, T. G. (2005). Development of tourism sustainability assessment proceudure: A conceptual approach. *Tourism Management, 26*, 431–445.

Lenzen, M., Sun, Y., Faturay, F., Ting, Y., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature Climate Change*. https://doi.org/10.1038/s41558-018-0141-x

Meng, S., Pham, T., Dwyer, L., & Grant, B. (2020). Carbon price impacts on the Chinese tourism industry. *Journal of Travel Research, 60*(2), 370–383.

Meng, W., Xu, L., & Hu, B. (2016). Quantifying direct and indirect carbon dioxide emissions of the Chinese tourism industry. *Journal of Cleaner Production, 126*, 586–594.

One Planet. (2021). Glasgow declaration. Available: https://www.oneplanetnetwork.org/sustainable-tourism/glasgow-declaration Accessed 8 October 2021.

Perch-Nielsen, S., Sesartic, A., & Stucki, M. (2010). The greenhouse gas intensity of the tourism sector: The case of Switzerland. *Environmental Science and Policy, 13*(2), 131–140.

Pham, T., Kookana, J., & Osborne, D. (2014). *State tourism satellite accounts 2012–13* (p. 2014). Canberra, April: Department of Resources, Energy and Tourism, Tourism Research Australia.

Pham, T., & Ngo, T. (2019). *Western Downs Region – Tourism Economic Assessment, a reported prepared for the Western Down Regional Council*.

Pham, T. D., Dwyer, L., & Spurr, R. (2009). Constructing a regional TSA: The case of Queensland. *Tourism Analysis, 13*(5/6), 445–460.

Scott, D., Amelung, B., Becken, S., Ceron, J. P., Dubois, G., Gössling, S., … Simpson, M. (2008). *Climate change and tourism: Responding to global challenges*. Madrid/Paris: United Nations World Tourism Organisation and United Nations Environment Programme.

Sharp, H., Grundius, J., & Heinonen, J. (2016). Carbon footprint of inbound tourism to Iceland: A consumption-based life-cycle assessment including direct and indirect emissions. *Sustainability, 8*(11), 1147.

Stats NZ. (2022). Greenhouse gas emissions (industry and household): year ended 2020. https://www.stats.govt.nz/information-releases/greenhouse-gas-emissions-industry-and-household-year-ended-2020.

Sun, Y.-Y., Cadarso, M. A., & Driml, S. (2020). Tourism carbon footprint inventories: A review of the environmentally extended input-output approach. *Annals of Tourism Research, 82*.

Sun, Y.-Y., Lin, P. C., & Higham, J. (2020). Managing tourism emissions through optimizing the tourism demand mix. *Tourism Management, 81*.

Tourism Research Australia. (2019). *REX Supercross database*. Canberra: TRA.

Unger, R., Abegg, B., Mailer, M., & Stampft, P. (2016). Energy consumption and greenhouse gas emissions resulting from tourism travel in an alpine setting. *Mountain Research and Development, 36*, 475–484.

United Nations. United Nations Framework Convention on Climate Change. https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&clang=_en.

UNWTO. (2010). *International recommendation for tourism statistics 2008, series M No. 83/Rev.1*. United Nations.

Vourdoubas, J. (2019). Estimation of carbon emissions due to tourism in the island of Crete Greece. *Journal of tourism and hospitality management, 7*(2), 24–32.

Whittlesea, E., Becken, S., Jago, L., & Pham, T. (2019). A new Indicator framework for Australia's visitor economy. In *A report prepared by Griffith institute for tourism*. Australia: Griffith University.

World Tourism Organization and International Transport Forum. (2019). *Transport-related CO2 emissions of the tourism sector – Modelling results*. Madrid: UNWTO. https://doi.org/10.18111/9789284416660

Wu, P., & Shi, P. (2011). An estimation of energy consumption and CO2 emissions in tourism sector of China. *Journal of Geographical Sciences, 21*(4), 733–745. https://doi.org/10.1007/s11442-011-0876-z

Zhang, J., & Zhang, Y. (2018). Carbon tax, tourism CO2 emissions and economic welfare. *Annals of Tourism Research, 69*, 18–30.

Tien Pham is an A/Prof at Griffith University. He has strong interests in tourism economic modelling including CGE modelling, TSA, demand analysis and climate change.

Xianming Meng (PhD) is a Senior Lecturer at New England University. His research interests include tourism economic modelling, environmental and energy modelling, and economic policy analysis.

Susanne Becken is a Professor at Griffith Institute for Tourism. Susanne contributes significantly to the Climate Change and Sustainable Tourism area.