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Overcoming information asymmetry in tourism carbon management: The application of a new reporting architecture to Aotearoa New Zealand

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ABSTRACT

Responding to the United Nations Sustainable Development Goals and Paris Climate commitments are urgent priorities facing many governments. Meeting these commitments will require new industry management architectures that align measures of progress (economic, environmental, human *and* social) with government structures, datasets, and reporting. Comprehensive emissions quantification and reduction targets for tourism must be a part of this new architecture. In this paper we propose a comprehensive Tourism Carbon Information System (TCIS), comprising four essential information components: national tourism carbon footprint, the carbon-economic linkage, drivers and decarbonization progress, and benchmarking. The TCIS is then tested and applied to Aotearoa New Zealand (2007–2013) to track tourism carbon performance and its decarbonization speed, compared to the national average across sectors. This critical information sheds light on future growth in tourism relative to the national greenhouse gas inventory and establishes the required mitigation trajectory for destinations to move onto a sustainable emissions pathway.

1. Introduction

The climate action transformation is underway. The United Nations Sustainable Development Goals 2015–2030 (SDGs) and the Paris Climate Agreement 2015 (L'Accord de Paris) point us in the direction of urgent transformation. The Paris Climate Agreement aims to stabilize global average temperatures below +2 °C relative to preindustrial levels based on the commitment of 196 countries (UNFCCC, 2015), with many signatories expressing the "intent to pursue a +1.5 °C target" (Scott, Hall, & Gössling, 2016, p. 1). It is critical that governments now respond to their sustainability commitments. This will require "… new governmental architecture that can give expression to the SDGs" (Boston & Berman, 2016, p. 17) which will guide our decision away from the current narrow measures of progress.

Typically, 'progress' continues to be assessed in relation to growth as measured in terms of gross domestic product (GDP). However some governments that are, coincidentally, currently led by visionary female prime ministers, including those of Iceland (Katrin Jakobsdottir), Scotland (Nicola Sturgeon) and Aotearoa New Zealand (Jacinda Ardern), are now eschewing GDP in favour of wellbeing and inclusive growth based on a comprehensive system of new measures. These measures include sustainable human well-being, sustainable ecosystems, social cohesion and equity, and measures of living standards. Such a system has become more important given the global tourism impacts of the COVID-19 pandemic (Gössling, Scott, & Hall, 2020; Lenzen et al., 2020). Alongside increasingly frequent global bioshocks, all such measures require, as a starting point, a demonstrated commitment to reducing carbon emissions (Gössling & Higham, 2020).

One urgent challenge facing tourism that must be central to the COVID-19 tourism rebuild is to seek a balance between tourism revenue (SDG 8 Decent work and economic growth) and its impact on climate change (SDG 13 Climate Action). Tourism historically has outperformed the global economy in terms of annual growth but, at the same time, faces the difficulty of decoupling growth from increasing carbon emissions. Given its significant contribution to global CO_2-e emissions (8%) and its strong growth rate (3% annually), tourism emissions are expected to become an ever greater contributor to the carbon budget of the global economy between 2020 and 2060 (Lenzen et al., 2018; Scott, Peeters, & Gössling, 2010; WTO-UNEP-WMO, 2008).

To date, the universal inability to stabilize and reduce tourism carbon emissions is largely attributed to longstanding policy settings that give priority to economic growth (Becken, Whittlesea, Loehr, & Scott,

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2020; Gössling, Hall, & Weaver, 2009). While countries have leveraged tourism development to expand demand and consumption, there is a lack of meaningful and proactive strategies for mitigating tourism emissions. In 2009, an ambitious tourism reduction target was put forward, aiming at tourism emissions reductions of 25–30% by 2020 and 50% by 2035 from the base year 2005 (WTTC, 2009). Despite this aspirational vision, very few countries have identified cohesive tourism-related mitigation strategies and even fewer have yet implemented such policies (Becken et al., 2020). One exception is the European Union's Emissions Trading System (ETS) for aviation, which since 2012 has required flights from, to and within the European Economic Area (EEA) to comply with a cap-and-trade system to reduce aviation emissions (European Commission, 2020). With limited global commitments on tourism, a report that reviewed 34 OECD members regarding their state of policy-making found that "*current government policy for (tourism) mitigation is still in its infancy, and does not seem to reflect demands by global business to enact climate policy*" (OECD-UNEP, 2011, p. 14). The same observation was recently reported by Becken et al. (2020). They note that tourism climate policy is largely ignored within national governance and policy processes related to climate change, based on their extensive review of 101 policy documents from 61 countries.

Information asymmetry in government data and analysis systems is an important factor underlying current deficient policy settings. The economic impacts of tourism are measured, reported and promoted in various forums ranging from the annual publications of tourism's economic significance for 185 countries by the World Travel and Tourism Council (2020), to regional assessments by national tourism bureaux, and small-scale event and festival evaluations. On the contrary, information about the tourism carbon footprint is rarely available for policy makers because relevant information is not directly compiled and traced in the national Greenhouse Gases Inventory. Although the call to expand current tourism statistics to include a comprehensive and transparent tourism carbon footprint indicator was proposed over a decade ago by the World Tourism Organization (2008), the World Travel and Tourism Council WTTC (2009) and members of the academic community (Becken & Patterson, 2006; Scott et al., 2010), any comprehensive efforts to develop tourism carbon footprint inventories remain notable only by their absence. To date, fewer than 10 countries[1] have documented their national tourism carbon emissions via academic research and only Sweden and New Zealand have established rigorous official tourism emissions figures (UNWTO, 2019b).[2]

The absence of comprehensive measures of tourism carbon emissions (alongside long-established economic measures of tourism), represents a failure at the global level to develop and maintain the data systems required to inform national and global leadership in times of urgent transformation. This has hindered the implementation of tourism climate policy at multiple levels, including providing sector-specific mitigations objectives, defining workable actions, and providing measures that can hold stakeholders accountable (Becken et al., 2020). As a result, the majority of tourism GHG emission reduction policies are mostly related to voluntary instruments among the WTO member states (UNWTO, 2019a). The inability to implement well-defined tourism carbon mitigation policies at the national level is due to the lack of rigorous insights to guide policy instruments and measure progress towards clearly stated carbon mitigation targets.

A critical understanding of tourism consumption and emissions at the national level can be facilitated by a comprehensive Tourism Carbon Information System (TCIS). In this paper we propose such a system which is built upon four pillars of information that are required to elucidate the relationship between tourism consumption and tourism carbon emissions. We then apply to the proposed TCIS to the case of New Zealand (2007–2013) to analyse tourism carbon performance and decarbonization over time, compared to the national average. We argue that these data are critical to the formulation of effective tourism carbon policy, to ensure that tourism policy interventions are achieving reduction targets in line the SDGs and Paris Climate commitments.

2. The Tourism Carbon Information System

The IPCC (2006) commitment to the national Greenhouse Gas Inventory system set up legally binding emissions reduction targets for all Annex I and Annex II countries following the Kyoto Protocol. This inventory system supports a fundamental data architecture to reduce carbon emissions at the global level. With the basic inventory in place, decision-making about climate change can begin to consider valuation and mediation among diverse values, especially from the economic and social perspectives. The United Nations recognised this need, and promoted an internationally compatible "System of Economic and Environmental Accounting (SEEA)" to facilitate the trade-off analysis of greenhouse gas emissions (GHG), GDP, and other environmental goods (United Nations, 2014). Our analytical framework is somewhat analogous to this process. We start with the tourism carbon footprint inventory, followed by the linkages between tourism GDP and GHG, and then move on to the trade-off analysis regarding decomposition and benchmarking.

Within the proposed framework, four sets of information (referred to here as pillars) are required (Fig. 1). The first pillar presents the tourism carbon footprint (CF) to establish the sheer amount of environmental externality (GHG) attributable to travel and tourism. The second pillar addresses the linkages between tourism's economic contribution and emissions to profile the trade-off between GDP and CO_2. The third pillar traces the underlying factors that detract from or improve tourism carbon performance, which informs the speed of tourism decarbonization. Lastly, the fourth pillar ranks the carbon performance of tourism against other sectors in the economy to inform whether or not prioritizing tourism is likely to be an effective pathway to decreasing total national carbon emissions.

2.1. *First pillar: The carbon footprint of national tourism consumption*

Conventional analysis and policy tend to ignore tourism and its relationship with carbon emissions as it is not considered to be a clearly defined discrete economic sector. This is now recognised as being an untenable oversight because tourism is a major energy users and producer of emissions (Lenzen et al., 2018; Patterson & McDonald, 2004). The first pillar of information is required to provide a systematic estimation of national tourism carbon emissions to ensure that a destination's tourism emissions are clearly and accurately quantified. Pillar 1 information reveals tourism's contribution to national emissions in relative (percentage) and absolute (total emissions) terms.

2.2. *Second pillar: The linkage of tourism receipts and its carbon efficiency*

The second pillar quantifies the linkage between tourism's contribution to the economy and its impact on emissions, via the greenhouse gas emissions/GDP indicator (that is, monetary emissions intensity). This information takes into account the economic significance of tourism using an efficiency proxy. The monetary intensity of tourism

[1] This includes Australia (Dwyer et al., 2010), China (Meng, Xu, Hu, Zhou, & Wang, 2016), Iceland (Sharp, Grundius, & Heinonen, 2016), Japan (Kitamura, Ichisugi, Karkour, & Itsubo, 2020), New Zealand (Becken & Patterson, 2006), Portugal (Robaina-Alves et al., 2016), Spain (Cadarso, Gómez, López, Tobarra, & Zafrilla, 2015) and Taiwan (Sun, 2014).

[2] Canada and Italy implemented an exploratory study to combine the System of Economic and Environmental Accounting (SEEA) and Tourism Satellite Account (TSA) to estimate tourism carbon emissions in 2008 and 2005, respectively. So far, only Sweden (Daniels, 2018) and New Zealand (Statistics New Zealand, 2020) have published official statistics of tourism carbon emissions.

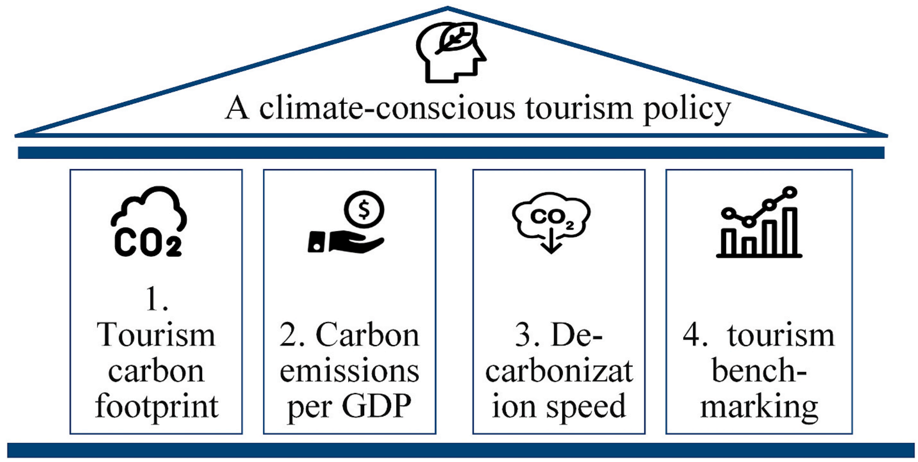

Fig. 1. The tourism carbon information system (TCIS).

emissions assists in the design of policies with a dual mandate in mind; to simultaneously maintain economic prosperity and advance climate action. If the tourism industry can operate at an optimal energy efficiency, tourism consumption will achieve with reduced energy demand. This allows tourism output to be maintained while reducing the environmental burden of tourism. Under this scenario, a mandatory reduction of economic activity is not required and tourism expansion is possible if an efficient solution can deliver reduced energy dependence (Akimoto et al., 2008). Conversely, if visitors decide to travel further, faster, use more aviation and more luxury experiences (Airbus, 2017; Peeters; Landré, 2012), this will result in reduce carbon efficiency over time, as expressed in higher emissions per dollar GDP.

2.3. Third pillar: The speed of reducing tourism carbon footprint over time

Measuring the decarbonization of tourism over time is needed to track progress towards reducing emissions at the industry level. This analysis seeks to quantify and understand how rapidly tourism businesses can decrease their emissions (Robaina-Alves, Moutinho, & Costa, 2016; Sun, 2016). The decarbonization of tourism is primarily determined by technological and operational improvements, leading to improved energy efficiency per unit operation and subsequently lower emission levels. Other means of accelerating the tourism carbon reduction trajectory are also available to policy-makers and businesses through behavioural changes and market-based carbon management (Becken, Simmons, & Frampton, 2003; Gössling, Scott, & Hall, 2015). A decomposition analysis seeks to model and provide insights into how effective these factors are in driving industry progress on carbon mitigation. By understanding the relationship between tourist consumption and the tourism carbon footprint allows policy-makers and destination managers to anticipate sectoral emission pathways when expanding visitor consumption under various scenarios.

2.4. Fourth pillar: Benchmarking tourism against other sectors

The last pillar compares the carbon performance of tourism against other sectors based on the emissions intensity indicator (emissions/GDP). This indicator informs the marginal effect of expanding the national carbon inventory when earning one-dollar GDP through tourism versus other alternatives (e.g., car manufacturing). This information further substantiates the effectiveness of current mitigation designs on tourism, either through subsidies, regulatory instruments, market-based measures, agreements, or information campaigns (OECD-UNEP, 2011). This information reveals whether priority attention should be given to tourism to reduce national emissions.

3. Analytical Framework: The New Zealand Tourism Carbon Information System

In this section we present the analytical procedures used to construct the tourism carbon information system (TCIS). While the analysis is tailored to the case of New Zealand, the proposed procedures can be applied equally to different national and subregional scales of analysis. The proposed procedures offer high levels of flexibility and several analytical components can be adjusted to reflect the local contexts under the umbrella TCIS framework.

3.1. System boundary

Since tourism is a composite good provided by national and foreign producers, and consumed by residents and non-residents at the destination, it is important to disclose the components that are included in the tourism carbon emissions calculation. Different allocation principles have been adopted to define the tourism carbon footprint and great variation exists in what components are included (Gössling, 2013; Sun, Cadarso, & Driml, 2020; Sun, Lenzen, & Liu, 2019). The choice of system boundary is critical, and needs to ensure that the tourism carbon footprint indicator is comprehensive, valid and internationally comparable in order to maximize its utility and value in informing tourism climate policy.

The United Nations World Tourism Organization (WTO) and the United Nations Statistics Division have developed the "Measuring the Sustainability of Tourism (MST)" system to quantify economic, environmental and cultural impacts of tourism at the national and subnational level (UNWTO, 2018). MST incorporates the frameworks of tourism satellite account (TSA) and the System of Environmental-Economic Accounting - Central Framework (SEEA-CF) capture the structure and inter-linkages between the economy and the environment. The MST framework allows tourism to be comprehensively assessed within the national economic and environmental accounts, providing various measurement and monitoring programmes relating to sustainable tourism.

Thus, we follow the same principle of MST and combine TSA-SEEA with environmentally extended input-output (EEIO) modelling for the carbon footprint calculation, which is recommended as an extension from the existing MST framework (UNWTO, 2017b). This system boundary covers emissions associated with tourist consumption on transport, accommodation, food, recreation and shopping within the destination arising from domestic tourism, inbound tourism and local expenditure associated with outbound journeys (UNSD-EUROSTAT-OECD-WTO, 2008). This framework also includes emissions relating to residents and foreigners for their use of aircraft and other long-distance transport equipment registered in the country of reference (United Nations, 2014). In the example of New Zealand, this considers New Zealand residents and inbound tourists who fly on New Zealand-registered airlines. Emissions associated with foreign carriers (e.g., Qantas, Emirates etc.) operating to and from New Zealand are not included. This treatment is consistent with the SEEA principle that states, "*regardless of the distances travelled, the number of places of operation, whether the transport service is supplied to non-residents or whether the transport service is between two locations not within the resident country—all revenues, inputs (including fuel, wherever purchased) and emissions are attributed to the country of residence of the operator*." (UNSD, 2014, p. 18). The inclusion of international aviation emissions in TCIS reduces a longstanding loophole for a rapidly increasing component of tourism-related emissions (Dwyer, Forsyth, Spurr, & Hoque, 2010).

3.2. The New Zealand study context

New Zealand is utilized in this paper to investigate if and how the TCIS may assist a country to develop information systems that can usefully inform climate conscious tourism policy. New Zealand offers an excellent study context. It is a prominent international destination in the global tourism system, despite being distant from key source markets and dependent on high carbon, long-haul aviation (Sun & Lin, 2019). Tourism has long been an important sector of the New Zealand economy, with a history of sustained high growth in international arrivals driven since 1999 b y the enormously successful '100% Pure New Zealand' international marketing campaign (Ateljevic & Doorne, 2002; Morgan, Pritchard, & Piggott, 2002). The efficacy of the '100% Pure New Zealand' brand however has been subject to increasing scrutiny because of the carbon intensity of long-haul aviation, raising questions of climate hypocrite.

The New Zealand political context is also very relevant to our research questions. The Labour-led Jacinda Ardern coalition government was elected in October 2017 on a mandate that promised the extension of measures of national economic performance beyond GDP. In 2018, it delivered its first 'Well-being Budget', which addresses well-being measures based on the four capitals (financial, natural, human and social). These are now analysed in official New Zealand statistical databases, both nationally and regionally, to inform all government policy. Statistics New Zealand *Tatauranga Aotearoa* manages databases that measure well-being and quality of life in New Zealand in a way that includes but extends far beyond measures of GPD (*see* Statistics New Zealand Tatauranga Aotearoa (2018)). New Zealand's system of national accounts provides access to the datasets required to conduct this research. This includes the Tourism Satellite Account (updated annually), the energy end use database (updated annually), and national input-output tables (updated once every five years). This allows our analysis to be performed for the period of year 2007 and 2013 based on the latest available datasets.[3]

Perhaps most importantly, the New Zealand government is committed to climate action. This has been clearly signalled in its commitment to the Paris Climate Accord UNFCCC (2015), and backed up in domestic acts of legislation including the Net Zero Carbon 2050 Act (Ministry for the Environment, 2019a), the Well-being budget framework (2018) and the creation of the Climate Change Commission (2019). Within this national context, the urgency of tourism climate action specifically has been brought to the fore by the recent publication of a report on tourism by the Parliamentary Commissioner for the Environment (New Zealand) (2019), whose office independently advises government on environmental issues and policy responses. This report provides a comprehensive and confronting analysis of broad ranging sustainability issues, highlighting tourism carbon emissions as a critical challenge facing the tourism industry and the wider New Zealand economy. This report highlights the importance of research-led efforts to decarbonize tourism as an important part of the wider government well-being and climate action agenda. Our research responds to this call for action.

3.3. Calculation

TCIS adopts the environmentally extended input-output model (EEIO) to trace all emissions occurring in the chains of production and distribution through economic-environmental accounts. The appealing feature of EEIO is its ability to present a complete analysis of the direct and indirect tourism carbon emissions (Dwyer et al., 2010; Sun, 2014). In addition, EEIO simultaneously quantifies economic and environmental changes due to tourism, displaying GDP and GHG side by side (Miller & Blair, 2009; Wiedmann & Minx, 2008). This assists us to synthesise the trade-offs that can arise between tourism and many of its impacts to the destination.

The first step of EEIO is to calculate the tourism CF by way of tracing visitor expenditures (***Y***) through the tourism satellite account (TSA) (Equation (1)). This determines the extent to which products and services are produced by New Zealand firms to meet tourist demand. The next step calculates direct and total emission multipliers per dollar sales by sectors (***B***). This step requires the harmonization of the input-output table and the energy database. In the current analysis, 43 sectors are aligned, and 9 are important tourism-related sectors.[4] The calculation proceeds by multiplying visitor expenditure with sector specific carbon emissions multipliers for 2007 and 2013 using the carbon emission factors from the Energy End Use Database (***R***) (EECA, 2019) and the New Zealand input-output tables ($\boldsymbol{A_d}$). The calculation is as follows.

$$Q_d = R\,(I\text{-}A_d)^{-1}Y = BY \qquad \text{(Equation 1)}$$

Where.

Q_d = Total domestic emissions emitted directly and indirectly.

Y = Visitor expenditure.

A_d = Domestic technical input coefficients.

I = Identity matrix.

R = Diagonalized matrix of emission produced per dollar's worth of output by industry; the carbon emission intensity.

B = Total emissions emitted per dollar's worth of output by industry.

Besides emissions that are produced within the New Zealand economy, additional emissions are emitted by foreign producers if they supply goods and services to New Zealand's tourism business. The magnitude of embedded emissions on imported products/services is estimated using the Domestic Production Technology (DTA) assumption (Wiedmann, 2009). This assumes that all imports are produced based on the same technology as those used by New Zealand firms. In the case of New Zealand, this approach is likely to lead to an underestimation as New Zealand's major trade partners, such as Australia and China, are more carbon-intensive in their production structures than New Zealand (they tend to use non-renewable rather than renewable energies, most notably coal). The computation of the embedded carbon footprint of imports is as follows (Wood & Dey, 2009):

$$Q_m = R\,(I - A_d)^{-1}A_m(1 - A_d)^{-1}Y_d + R\,(I - A_d)^{-1}Y_m, \qquad \text{(Equation 2)}$$

Where.

Q_m = GHG emitted for goods produced in foreign industries to meet the final demand and intermediate input demand domestically.

Y_d = Visitor expenditure on domestic products.

[3] The 2019 input-output table, which will cover the five-year period from 2014 to 2018 will be available in 2021, at which point it will be possible to conduct a comprehensive TCIS analysis for the period 2007 to 2018.

[4] Accommodation, food and beverage services, arts, recreational and gambling, retail trade – fuel, transport, postal and warehousing (non-transport), road transport, rail transport, other transport, and air and space transport.

Y_m = Visitor expenditure on imported goods.
A_m = Imports technical input coefficients.
Emissions from tourism-related private motor vehicle use are estimated separately from the EEIO model. The process first converts how much visitors pay for fuels at the pump to litres of petrol and diesel based on the average fuel retail price (MBIE, 2019b). The physical quantity of petrol and diesel used by tourists is then multiplied with emission factors per litre (Ministry for the Environment, 2019b) to calculate greenhouse gas emissions.

The last step of the analysis employs a decomposition method to identify forces and their relative influence in driving or mitigating overall tourism emissions. Since the decomposition analysis is a well-developed approach, there is a variety of decomposition formula and factors that can be used in the model (see Ang (2004), Ang (2005) and Hoekstra and van den Bergh (2003) for review). The simple deposition model in the tourism literature includes the structure decomposition analysis that uses two variables to capture demand (total visitor expenditure and spending profile) and two variables to understand supply (technology and economic structure) (Sun, 2016). More complex approaches are also available that employ index decomposition analysis to further our understanding with respect to how different energy sources are being used, how labour and capital are adopted to promote innovation, and whether firms can generate higher value added per unit energy use (Liu, Feng, & Yang, 2011; Robaina-Alves et al., 2016; Zha, Tan, Yuan, Yang, & Zhu, 2020). Ultimately, the choice of decomposition model is driven by ease of use, simplicity, and relevance for policy (Ang, 2004).

In this study, we employ a structure decomposition analysis (SDA) that allocates the difference of carbon footprint in New Zealand into four factors, including:

1. The final demand effect: changes in total visitor consumption.
2. The distribution effect: changes in visitors spending profile toward each type of item/service (e.g., spend more on air transport versus sightseeing at different time periods).
3. The intensity effect: changes in production technology, proxy through carbon emissions per dollar output.
4. The Leontief effect: changes in economic structure, proxy through total input requirement per unit of sector output.

In contrast to other decomposition methods, this approach is simple enough to be understood, while complex enough to provide a thorough explanation, drawing information from both supply and demand components. The formula to decompose the direct and indirect emissions is specified as below (Sun, 2016).

The difference of tourism carbon emission between two time periods

$$= \text{Total emissions}_{t+1} - \text{Total emission}_t = D_{int} + D_{ltf} + D_{dis} + D_{fd}$$

Intensity effect, $D_{int} = \Delta CBDY + 1/2\Delta C(\Delta BDY + B\Delta DY + BD\Delta Y) + 1/3\Delta C\,(\Delta B\Delta DY + \Delta BD\Delta Y + B\Delta D\Delta Y) + 1/4\Delta C\Delta B\Delta D\Delta Y$

Leontief effect, $D_{ltf} = C\Delta BDY + 1/2\Delta B\,(\Delta CDY + C\Delta DY + CD\Delta Y) + 1/3\,(\Delta C\Delta DY + \Delta CD\Delta Y + C\Delta D\Delta Y) + 1/4\Delta C\Delta B\Delta D\Delta Y$

Distribution effect, $D_{dis} = CB\Delta DY + 1/2\,\Delta D(\Delta CBY + C\Delta BY + CB\Delta Y) + 1/3\Delta D\,(\Delta C\Delta BY + \Delta CB\Delta Y + C\Delta B\Delta Y) + 1/4\Delta C\Delta B\Delta Y$

Final demand effect, $D_{fd} = CBD\Delta Y + 1/2\,\Delta Y(\Delta CBD + C\Delta BD + CB\Delta D) + 1/3\Delta Y\,(\Delta C\Delta BD + \Delta CB\Delta D + C\Delta B\Delta D) + 1/4\Delta C\Delta B\Delta D\Delta Y$

Where.
ΔC is the difference of GHG emission factor between two time periods.
ΔB is the difference of the Leontief inverse matrix between two time periods.
ΔD is the difference of standardized spending profile to sectors between two time periods.
ΔY is the difference of the tourism spending between two time periods.

4. Results: The New Zealand Tourism Carbon Information System

In this section we present the results of the tourism carbon information system (TCIS) for New Zealand to demonstrate the feasibility and applicability of the proposed analytical framework and to outline how it may help to reveal key information that has not been available previously in current national data and reporting systems in New Zealand or anywhere else in the world. In the process, we quantify the magnitude of direct emissions produced by tourism firms, indirect emissions by suppliers, and emissions associated with tourism-related private vehicle use. In addition, benchmarking is performed to evaluate if, and if so, to what extent, New Zealand tourism was decarbonized between 2007 and 2013, and to rank tourism's carbon emission efficiency per dollar GDP against other sectors in the economy.

Pillar 1: The carbon footprint of national tourism consumption in New Zealand

Based on the New Zealand TSA, tourism contributed $23.9 billion in visitor expenditure in 2013, including business & governmental travel, household demand (domestic travel and local spending for outbound travel), and inbound tourism (Statistics New Zealand, 2019). Expenditures arising from flights to and from New Zealand serviced by foreign carriers are not included here. In addition, residents' expenditures at foreign destinations are not considered by the TSA, and therefore are excluded in this analysis.

Visitor expenditure contributed about $9.5 billion GDP in direct effect and $19.2 billion GDP in total effects (Table 1). In terms of carbon emissions, the direct emissions of tourism were 4.4 million tonnes (Mt), total domestic emissions were 5.8 Mt or 6.3 Mt if emissions of imports are included. Emissions from private vehicle use were significant, contributing 3.4 Mt. In other words, to support the $23.9 billion of visitor expenditure in New Zealand, the global climate impact is about 9.8 Mt CO_2-e, of which 46% is produced by domestic tourism business, 35% from private vehicle use, 14% from domestic suppliers and 6% from international producers (Table 1).

Domestic leisure travel by household contributes approximately 42% of New Zealand tourism CO_2 because of the extensive use of air transport and private vehicles, followed by inbound tourism (36%), and domestic business and governmental travel (22%). From the sector perspective, transport is the most critical service that contributes to the tourism carbon footprint. The aviation sector accounts for 70% of New Zealand tourism's direct emissions or 55% of tourism's total emissions. This pattern is consistent with other island destinations. For Australia and Taiwan, respectively, 49% and 45% of the tourism CF is produced by the aviation sector (Dwyer et al., 2010; Sun, 2014). In sum, air and road transport contribute around 70% of total tourism sector emissions in New Zealand.

Pillar 2: New Zealand tourism receipts and carbon efficiency

The second pillar contrasts national and tourism-specific performance on GDP and emissions. For both parameters, international aviation from New Zealand-registered carriers is included. This ensures a fair base of comparison and avoids the loophole of excluding international aviation emissions when addressing carbon mitigation responsibility. In 2013, tourism contributed 9.2% of national GHG emissions in New Zealand (direct emissions, 5.3%, and emissions from private vehicle use, 4.0%), larger than its contribution to GDP (4.4%) in terms of the direct effect. If we include the indirect effect (impacts arising from the supply chain), tourism become less carbon intensive but its contribution to GDP

Table 1
New Zealand tourism carbon footprint, 2013.

	Tourism				National Total (with international transport)	Pct of tourism contribution (including international transport)
	Business and government demand	Household demand	International demand	Total		
Tourism expenditure (NZ$ millions)	3435	10,730	9777	23,942		
Pct	14%	45%	41%	100%		
Economic impacts						
Direct GDP (NZ$ millions)	1248	4189	4075	9512	198,991	4.8%
Total GDP (NZ$ millions)	2642	8687	7874	19,204		9.7%
Environmental impacts (kt CO2e)						
1. Direct emissions	1183	1113	2124	4420	84,034	5.3%
2. Indirect emissions from domestic suppliers	211	618	516	1345		1.6%
3. Emissions from private motor vehicle	620	2132	597	3349		4.0%
Total emissions in New Zealand	2029	3913	3256	9198		10.8%
4. Imported GHG	95	247	227	569		
Total emissions globally	2109	4109	3465	9684		
Pct	22%	42%	36%	100%		

(9.7%) is remains less than its share on the national emissions (10.8%). In 2013, New Zealand produced $199 billion value-added and 84 Mt emissions.[5] This corresponds to 0.42 kg CO_2-e per dollar GDP. In contrast, the direct tourism carbon efficiency is about 0.83 kg/GDP, almost double the New Zealand national average.

Pillar 3: A Decomposition Analysis of New Zealand Tourism Carbon Emissions

From 2007 to 2013, tourism expenditure increased from $20.1 billion to $23.9 billion, allowing tourism total GDP to grow from $16.1 billion to $19.2 billion (19.2%) (Table 2). At the same time, the New Zealand tourism carbon footprint (imports are not considered) increased by a smaller fraction (6.7%) from 8.5 Mt to 9.1 Mt. Direct tourism carbon emissions increased by 5.1% and indirect tourism carbon emissions increased by 1.3%. The most substantial increase came from tourists' use of private vehicles, where emissions increased 11.4%. The growth of New Zealand tourism spending however does not lead to a similar growth of emissions from foreign suppliers. Rather, the embedded emissions were reduced by 131 Kt, indicating a relatively low dependence of New Zealand firms on carbon intensive foreign suppliers. Our analysis indicates that the net change in New Zealand tourism emissions arising from domestic producers between 2007 and 2013 was approximately 576 kilotonnes (kt). The reduced embedded emissions of imports explain lower growth in the global carbon impact (445 Kt) arising from tourism activities in New Zealand.

Table 2
Tourism contribution to the New Zealand in GDP and carbon emissions, 2013.

	2007	2013	Difference	Pct change
Total visitor spending ($millions)	$20,083	$23,942	$3859	19.2%
Tourism carbon emissions (kt CO2e)				
Direct tourism emissions	4205	4420	215	5.1%
Indirect tourism emissions	1328	1345	17	1.3%
Emissions from vehicle use	3005	3349	344	11.4%
Total emissions in New Zealand	8538	9114	576	6.7%
Imported emissions	700	569	−131	−18.7%
Total emissions globally	9239	9684	445	4.8%

Using the structure decomposition analysis, we are able to break down the net increase of 445 kt CO_2-e into four components (Fig. 2). Final demand effect is the largest factor for driving tourism emissions. An increase of tourism spending from 2007 to 2013 (19.2%) resulted in an increase in the tourism CF of 1453 kt, assuming other factors remained constant. In addition, visitors in 2013 consumed more dairy products and purchased more souvenirs than in 2007. These components are carbon intensive per unit sales. This change in consumption patterns (distribution effect) helps to explain the increase of 71 kt CF.

Both the Leontief effect (how tourism firms work with suppliers) and the intensity effect (how much energy firms have to use in order to produce per dollar output) improved the tourism carbon performance. Tourism firms were found to have used less energy-intensive inputs over time, especially with respect to imports, and this helped to cut back 339 kt CF. In addition, firms seemed to progress very well with technology improvement. This amounted to a reduction of 740 kt CF.

If we sum these four effects, we arrive at a net increase of 445 kt of tourism CF from 2007 to 2013. This result supports the observation that the efficient use of energy among domestic firms (the intensity effect) is able to offset half of the additional energy required to satisfy the net increase of tourism demand. In addition, the structure of New Zealand tourism businesses has experienced substantial changes, leading to less dependence on energy-intensive goods, both domestically and imported. This contributed to a 20% reduction of emissions from the growth in additional tourism demand. Overall, during the time period under analysis (2007–2013), New Zealand's tourism carbon emissions (not accounting for imports) expanded at approximately one-third the speed of the tourism expenditure.

Pillar 4: Benchmarking tourism against other sectors of the New Zealand economy

The benchmarking analysis compares the economic and environmental performance of tourism with other sectors in the national economy to highlight the trade-off of different development options. To be consistent, the benchmarking analysis demonstrates the direct economic effect and the direct carbon emission effect only. Indirect emissions of tourism, and emissions from private vehicle use are not included for benchmarking. This is because relevant information for other sectors on their indirect emissions or implicit emissions from households' consumption is unavailable.

For New Zealand, a benchmarking analysis is implemented by comparing the carbon performance of tourism firms against 43 sectors (44 sectors were analysed including tourism). The comparison is based on two economic indicators – sales and GDP, and two environmental

[5] This includes "energy use" 32.1 Mt, "industrial processes and product use" 4.8 Mt, "agriculture" 39.3 Mt, "waste" 4.3 Mt, and "international aviation" 3.5 Mt.

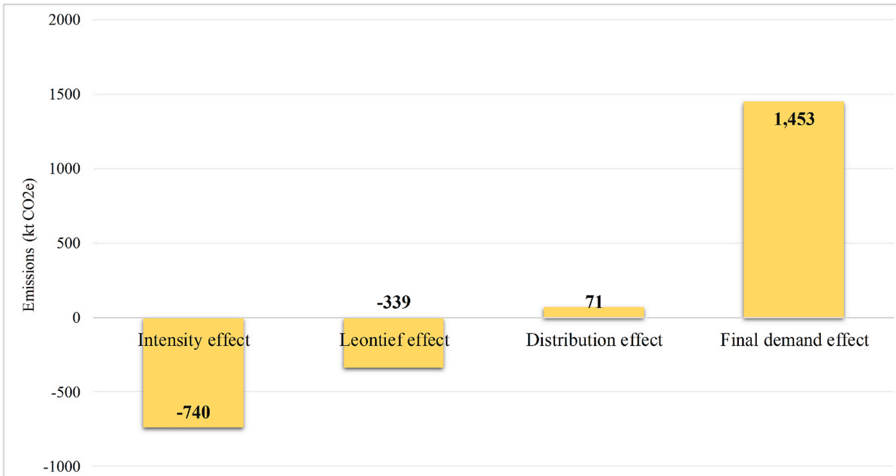

Fig. 2. Decomposition results of New Zealand tourism CF, 2007–2013.

proxy indicators - GHG emissions and GHG/GDP ratios, respectively.

The benchmarking analysis documents the economic significance of tourism in New Zealand, but at the same time, points out the influential role it plays as a contributor to the national emissions inventory (Table 3). In 2013, tourism ranked 4th in contributing to sales; 5th in contributing to national GDP; 1st in sector level GHG emissions; and 12th in its GHG/GDP efficiency.[6]

Among the top 5 GDP-contributing sectors in New Zealand, tourism produced more emissions per unit GDP than the other four sectors, due to its extensive use of air transport and road transport. This places tourism as the primary sector that produces the largest energy-related CO_2 emissions in New Zealand. It is important to note that the ranking is concerned only with emissions produced from energy use among industries. The ranking does not take into account emissions from enteric fermentation within agriculture, a process that produces CH_4 from livestock digestive systems, or N_2O emission from manure or fertiliser, which is an important GHG component (48%) in New Zealand economy (Ministry for the Environment, 2019b).

Compared to the tourism emissions statistics from 1997/1998 (Becken & Patterson, 2006), the rapid increase of tourism volume in New Zealand has substantially expanded tourism emissions over time. Inbound tourism now accounts for a bigger share in the overall tourism footprint as it increased from 25% to 36%. In addition, tourism's ranking with respect to other sectors' emissions has risen from the 5th (worst) place among 26 sectors in 1997/98 to 1st out of 43 sectors in 2013. The continued growth of tourism has demonstrated a clear pattern that this sector is posing a bigger environmental pressure on our climate.

In Fig. 3, an emissions intensity curve displays the ranking of sectoral carbon efficiency against the accumulated GDP contribution for year 2013. It showcases the pattern of industry's carbon efficiency and how individual sectors contribute to economic wealth collectively. In the case of New Zealand, the majority of GDP is supported by low carbon industries as related to energy use. Thirty-two (32) out of 44 sectors are able to produce economic outputs with a carbon efficiency lower than tourism, and in aggregate these 32 sectors contribute about 89% of national GDP. Tourism carbon efficiency ranks 12th, lower than primary metal manufacturing, air transport, fishing, road transport, and dairy product manufacturing.

Between 2007 and 2013, the New Zealand economy made progress on its environmental performance and delivered one-dollar GDP with 0.422 kg CO_2-e, corresponding to a 14% improvement across this timeframe (Table 4). In contrast, tourism was able to deliver a 10.7% efficiency gain across the same period. If we translate this into an annual performance, tourism is decarbonizing but at a rate (2.8%) that is lagging behind the national average (3.7%). The primary reason for tourism to decarbonize slower is because of the lack of meaningful progress on the aviation sector, which was only able to improve its carbon efficiency by 9% from 2007 to 2013.

Overall, New Zealand tourism emissions per dollar GDP is higher, and its decarbonization capacity is weaker than the national average. As long as this remains the case, future growth in tourism will inevitably contribute further to the national carbon inventory, unless tourism decarbonization initiatives can be successfully implemented.

5. Discussion

After nearly three decades of development since 1993, tourism satellite accounts have become the standard internationally compatible framework used to document the economic contribution of tourism to an economy through the lens of GDP, income, employment and tax indicators. The value of the TSA lies in its capacity to "analyse in detail all the aspects of demand for goods and services associated with the activity of visitors; to observe the operational interface with the supply of such goods and services within the economy; and to describe how this supply interacts with other economic activities" (UNSD-EUROSTAT-OECD-WTO, 2008, p. iii). This has been extensively recognised internationally. The TSA has since become a regular exercise for 63 countries, covering more than 85% of total global tourism consumption (WTTC, 2019).

The tourism carbon information system (TCIS) proposed in this paper embraces the same motivation for why TSA was originally created, which is that we need a uniform and comprehensive means of measurement and comparison of tourism and its carbon emissions. The Intergovernmental Panel on Climate Change has identified that one major barrier in climate change policy is "deficits of knowledge" (IPCC, 2014b) which we refer to in this paper as 'information asymmetry'. Lacking carbon-related information reduces perceptions of risk, willingness to change behavioural patterns, and adoption of social and technological innovations to reduce emissions. In addition, it hinders the inclusion of tourism as a sector in the national climate change policy,

[6] To avoid double counting, we have separated each sector's overall economic output and emissions into tourism-related outcome and non-tourism-related outcome based on the TSA tourism industry ratios. For example, tourists contributed 89% of total air transport output in 2013 and thus 89% of this sector's economic and environmental output goes to "tourism" and the rest 11% is assigned to the "air transport –non-tourism" sector. We apply this procedure across 43 sectors. This allows "tourism" to be presented as an independent sector and highlights its absolute contribution in the economy and to the environment.

Table 3
New Zealand top 5 industries by economic and environmental indicators, 2013.

Sales ($ million)		GDP ($ million)		GHG emissions (tons)		Emission/GDP coefficient (kg/$)	
1. Financing, insurance, real estate and business services	91,928	1. Financing, insurance, real estate and business services	58,470	***1. Tourism***	4420	1. Primary metal and metal product manufacturing	2.27
2. Construction	38,168	2. Wholesale and retail trade - non food	15,368	2. Petroleum, basic chemical and rubber product manufacturing	1716	2. Air and space transport (non-tourism)	2.00
3. Wholesale and retail trade – non food	27,625	3. Health care and social assistance	13,018	3. Dairy product manufacturing	1692	3. Fishing, hunting and trapping	1.31
4. ***Tourism***	23,942	4. Construction	11,893	4. Construction	1491	4. Rail transport	1.15
5. Health care and social assistance	20,680	***5. Tourism***	9512	5. Road transport (non-tourism)	1490	5. Dairy product manufacturing	1.00
						Tourism (12th place)	0.46
						National Average of all sectors	0.14

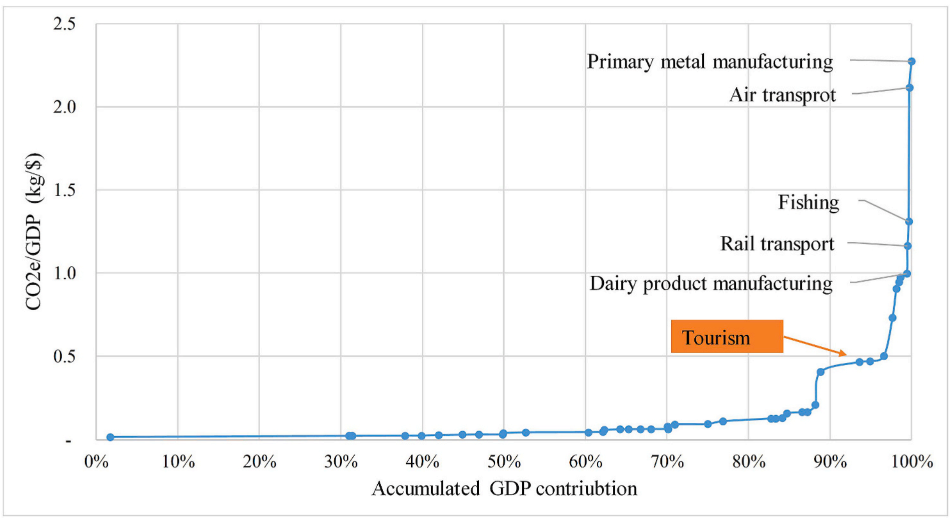

Fig. 3. Emission intensity curve of New Zealand, 2013

Table 4
Carbon efficiency of tourism and the national economy for New Zealand.

Year	2007	2013	Pct improvement	Annual decarbonization rate
Tourism GHG/GDP (kg/$)	0.914	0.817	10.7%	2.8%
National economy GHG/GDP (kg/$)	0.492	0.422	14.1%	3.7%

which leads to limited policy objectives and tangible indicators that are relevant to tourism (Becken et al., 2020). There is a growing agreement that climate policy will become more effective if coherent policy integration is being implemented to develop sectoral plans that address objectives, actions and measures (Schmidt & Fleig, 2018). In essence, the TCIS proposed here offers an opportunity to overcome deficits of knowledge among the public and achieve effective climate change policy integration for effective tourism carbon management.

5.1. *Applicability*

The TCIS provides a highly-feasible and cost-effective solution to the chronic lack of data that currently cripples effective tourism carbon management. This reporting architecture offers high exportability to other regional/national destinations because it is based on existing national statistics, including tourism satellite account, energy account, and the national input-output tables. No additional data collection is required. This enables national statistical offices to implement this reporting architecture with a minimum cost.

In addition, TCIS builds upon and extends from the Measuring the Sustainability of Tourism (MST) framework, an international statistical system that is recommend by the WTO and UN Statistical Division to measure tourism's role in sustainable development (UNWTO, 2018). Building upon this standard ensures that TCIS is (1) comprehensive – accounting for all domestic and international emissions driven by the tourism activities within a nation, (2) comparable – providing statistics and indicators within the framework of Systems of National Accounts so that indicators are internationally compatible, and (3) consistent – allowing benchmarking to be achieved across sectors of an economy.

TCIS not only can be adopted by the national tourism authorities but is easy to roll out to the global scale. This information framework is directly compatible with the economic impact report system from the World Travel and Tourism Council (WTTC) (2019), which provides annual tourism expenditure for 185 countries and 25 regions. This WTTC data structure can be readily integrated to calibrate the TCIS inventory once the global economic-environmental database is incorporated. This cost-effective international effort would provide an invaluable, real-time global TCIS database that estimates, benchmarks and ultimately assists the development of global and national tourism carbon mitigation policies.

5.2. *How the TCIS can inform tourism climate policy*

The TCIS offers more than a standalone national-level tourism carbon inventory. It provides relevant information regarding the decomposition and benchmarking of tourism carbon performance against other sectors of the economy. By incorporating these elements, we are able to identify two critical patterns—whether tourism is able to deliver reduced emissions per unit GDP and how fast can tourism decarbonize, compared to the national average. These two factors simultaneously determine whether future growth in tourism will contribute to increased national greenhouse gas emissions. Unless tourism can improve its performance on both premises, it is inevitable that the 'pro-tourism' policy that is currently embraced by most national governments will be incompatible with our commitments to stabilize and reduce global carbon emissions.

Information provided by the TCIS can inform and assist climate policy in two ways. First, this framework highlights the sectoral role tourism plays within the broader context of how a nation can achieve their international climate commitments. Within the Paris Climate Agreement, 40% of the 128 Nationally Determined Contributions and 35 Intended Nationally Determined Contributions acknowledge "tourism, either as a country priority, as part of their mitigation and adaptation strategies, or as a sector vulnerable to climate change" (UNWTO, 2017a). The proposed TCIS provides the building blocks for countries to pinpoint and better assess the linkages between tourism development and Nationally Determined Contributions. Detailed assessment can be implemented by combining the monetary intensity emissions of tourism (CO_2-e/GDP) with projected tourist expenditures to forecast absolute annual emissions post-2020. With this information in hand, the feasibility of leveraging tourism as a source for carbon mitigation in Paris Agreement can be fully evaluated.

Secondly, the emissions intensity of tourism can be utilized to set up sectoral mitigation targets. Randers (2012) suggested that a 5% annual reduction goal for GHG emissions per unit GDP is needed if global GHG emissions are to be 50% lower in 2050 than in 2010 while maintaining a 3.5% annual economic growth rate. The 5% reduction goal per annum however cannot be applied to all sectors because a uniform decarbonization trajectory and obligations will impose economic inefficiency (Krabbe et al., 2015). Rather, sectoral growth rates and market shares need to be considered. For businesses that embrace a higher activity growth and a higher initial performance on GDP, an aggressive abatement effort is required (Girod, van Vuuren, & Hertwich, 2013). In the case of New Zealand, international visitor arrivals were, prior to the Covid-19 pandemic, expected to grow at 4.6% annually, increasing from 3.7 million in 2017 to 5.1 million visitors in 2024 (MBIE, 2019a). Considering that tourism's share to the national GDP is significant, and its growth rate over the next decade is higher than 3.5%, New Zealand needs to decarbonize its tourism carbon intensity by more than 5% annually in order to halve tourism emissions over the next forty years. This sectoral approach in setting mitigation targets allows countries to quantify how far they are from their committed annual carbon reduction targets in tourism based on the current decarbonization speed.

The macro-level tourism emissions reduction goal (e.g., 5% per annum in the tourism sector) can also be converted to a micro-level reduction target at the corporate level. For countries that implement climate policy instruments, such as an emission trading scheme, carbon taxes, or scaled-up crediting programmes, the World Bank recommends that the emission intensity of all firms are ranked using the emission intensity curve (*see* Fig. 3) and to determine benchmarks that "*set targets and thresholds for environmental performance and to determine the distribution of instrument benefits and obligations*" (World Bank, 2017, p. 7). Such benchmarks allow firms to self-evaluate their performance relative to the sectoral average. Firms can then decide whether they will embrace broader technology improvement for financial rewards if they decarbonize above the abatement target. For those that are exempt from climate policy instruments, firms can also rely on the national tourism reduction goal to determine their company-specific targets using the firm-specific emissions/GDP indicator (see formula in Krabbe et al. (2015) for calculating the corporate emission reduction target). In addition, the firm level emissions/GDP indicator can be objectively used by companies, investors, and policymakers to track corporate climate performance and actions, ensuring greatly enhanced accountability.

6. Conclusion

Governments that have committed to the UN Sustainable Development Goals and Paris Climate Accord must develop and implement policies that are based on rigorous data and analysis that overcomes the exclusive historical focus on economic measures of tourism development. This study contributes to the literature by conceptualizing the Tourism Carbon Information System (TCIS), providing a new reporting architecture to overcome the information asymmetry that current inhibits and disables the climate policy setting. We argue that a comprehensive understanding of the relationship between tourism consumption and emissions can be facilitated by the four pillars of information that we outline in our analytical framework (*see* Fig. 1): tourism carbon footprint (pillar 1), carbon-GDP intensity (pillar 2), decarbonization (pillar 3), and benchmarking (pillar 4). The TCIS directly responds to the recent statement from the United Nations World Tourism Organization (UNWTO) that the "*tourism sector continues to need more evidence on essential climate-related information that is needed for better decision making*" (UNWTO, 2019).

The reporting architecture of the TCIS supports tourism policymakers with rigorous insights into how tourism performs in relation to the nation's climate commitments and economy, while contrasting the climate impact of tourism over other potential development opportunities. This is achieved by directly addressing three key questions in tourism carbon management: (1) does the tourism carbon footprint increase in a direct proportion to tourism consumption, (2) how carbon-intensive is tourism compared to other economic sectors, and (3) can annual carbon reduction targets in tourism be addressed based on the current mitigation strategies. We believe these constitute critical information requirements needed to understand whether future growth in tourism will contribute to increased national greenhouse gas emissions, and to provide knowledge into the required mitigation trajectory to achieve a carbon neutral pathway.

The applicability of the TCIS analytical framework is illustrated through the empirical case of New Zealand. We present a systematic analysis of the New Zealand's tourism carbon performance. The key observations arising from our four-pillar analysis indicate that tourism is the primary sector that produces the largest energy-related CO_2 emissions in New Zealand; its tourism carbon footprint expanded between 2007 and 2013 at approximately one-third the speed with respect to tourism expenditure growth; its carbon emissions per GDP figure was 2.3 times higher than the national average across all sectors; which was decarbonized during the period under analysis at an annual rate of 2.8%, lower than the national average of 3.7%. Based on these patterns, the trajectory of New Zealand tourism carbon emissions will not stabilize or decrease, but rather maintain a continuing strong growth pattern which is incompatible with New Zealand's Paris Climate commitments and Net Zero Carbon 2050 legislation.

Our empirical analysis of New Zealand tourism indicates that the TCIS offers critical baseline information and insights that cannot be solely identified by the existing Tourism Satellite Account, Greenhouse Gas Inventory, or the national Environmental-Economic Account. In addition, the high feasibility of the TCIS is assured because the system is built upon existing government statistical datasets that are compiled and published periodically based on international-agreed standards. The proposed analytical procedures safeguard the comprehensiveness and compatibility of the TCIS tourism carbon footprint, allowing it to be established within the system of National Accounts for policymaking, analysis and research. The TCIS is readily exportable to other national or regional contexts.

The TCIS that we have presented and applied in this paper offers comprehensive insights into tourism carbon emissions that are unprecedented globally. Our analysis provides new knowledge and detailed insights into where New Zealand tourism currently stands in terms of carbon emissions, and decarbonization pathways. It also raises new questions and challenges as to how we translate these understandings into feasible policies for deep decarbonization. Naturally the more ambitious our decarbonization goals are, the greater the need to accelerate the transformation through tourism policy and planning. Important avenues of further investigation that build upon our research are available to the academic community. The economic implications of transformation pathways in tourism, the feasibility and risk of current technology, integrated social and economic change, and linkages with other Sustainable Development Goals (employment, equality, poverty) all await future research (Clarke et al., 2014). Wider testing and application of the TCIS to other national tourism systems globally should also be the focus of further scholarly attention.

Credit author statement

Ya-Yen Sun: Conceptualization, Resources, Methodology, Formal analysis, Writing - original draft. James Higham: Conceptualization, Resources, Writing - review & editing

The impact statement

This paper answers an urgent call from the United Nations World Tourism Organization that the "*tourism sector continues to need more evidence on essential climate-related information* …" in order to inform tourism climate policy. In this paper we address the growing industry and academic voices calling for new government structures, datasets, and analytical systems required to rigorously inform tourism carbon management. To this end, we conceptualise a comprehensive Tourism Carbon Information System (TCIS), proposing four essential information components: national tourism carbon footprint, the carbon-economic linkage, drivers and decarbonization progress, and benchmarking. TCIS advices policymakers the critical information to determine precisely how future growth in tourism will impact upon national greenhouse gas emissions, and to inform the required mitigation trajectories for destinations to achieve a sustainable emissions pathway. This level of conceptual development and empirical analysis can be applied to different national and subregional levels.

Declaration of competing interest

None.

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