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Can Norway become a net-zero economy under scenarios of tourism growth?

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A R T I C L E I N F O

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A B S T R A C T

The Paris Agreement suggests that all countries engage in significant emission reductions. To stay within safe guardrails, usually defined as a maximum warming of 1.5 °C compared to pre-industrial times, this will mean decarbonisation within less than 30 years. This significant challenge is complicated because of growth in some sectors, such as tourism. This paper analyses emissions and economic output in Norway, considering national Tourism Satellite Accounts. Novel aspects of this paper include a longitudinal perspective covering 12 years through which critical developments and progress on emission reduction pathways can be assessed. Findings suggest that the carbon intensity of tourism (emissions per NOK) is more than twice the Norwegian economy average. Aviation in particular is a major barrier to emission reductions, as it generates 17% of national tourism revenue and 75% of direct tourism emissions. Trend extrapolation shows that tourism will be the largest emission sub-sector of the Norwegian economy by 2030. The Norwegian economy will have to decarbonise at a rate more than 30 times faster than its current rate, if it is to decarbonise to mid-century, while continuing on its observed economic growth trajectory.

1. Introduction

Emission reductions at various scales of tourism are a long-standing challenge to decarbonisation, as the global tourism system has consistently grown in its energy intensity and overall contribution to climate change (Gössling, 2002; Lenzen et al., 2018). This growth in stark contrast to global and tourism sector ambitions of limiting climate change to a maximum warming of 1.5 °C–2 °C in comparison to pre-industrial times, which may be achieved if fossil fuels are completely phased out by mid-century, along with corresponding cuts in other greenhouse gases (IPCC, 2021; Scott and Gössling, 2021). Destinations are particularly relevant in devising net-zero carbon strategies, because they combine a wide range of different tourism stakeholders such as transportation, accommodation, gastronomy, and activities (Sun and Higham, 2021). Destination managers can also make strategic decisions regarding favoured markets, as they may reduce marketing efforts or even de-market long-haul arrivals that entail a greater carbon footprint (Clements, 1989; Gössling et al., 2015).

To strategically reduce emissions, it is important to have an understanding where these arise, and how emissions are associated with tourism economic performance. This latter aspect is of particular importance because destinations will be confronted with difficult decisions when decarbonising, and to maintain economic performance will be paramount to justify change and to motivate stakeholders to support

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the transition. The net-zero carbon destination imperative should thus be pursued with a focus on increasing value for the destination, while also reducing losses incurred in various forms of economic leakage (Gössling and Higham, 2021). Measurements of emissions should be considered in relation to economic performance, for which input-output analyses have been identified as particularly useful (Lenzen et al., 2018; Sun et al., 2020). For instance, existing studies have concluded that it is desirable for destinations to decrease long-haul market shares (Becken and Shuker, 2019; Gössling et al., 2015; Sharp et al., 2016; Sun et al., 2020), to focus on sales of activities in order to increase revenue and average length-of-stay (Oklevik et al., 2019), or to avoid leakage by reconsidering the role and prominence of the platform economy and its cost (Gössling and Higham, 2021).

This paper seeks to provide quantitative insight on decarbonisation by considering the longitudinal (2007; 2012; 2019) development of emission intensities in Norway's national economy. Given the relevance of tourism in national development plans, specific emphasis is put on the question as to whether national tourism sector growth targets can be accommodated within national emission targets. Results complement bottom-up calculations (Grythe and Lopez-Aparicio, 2021), and combine environmental with economic indicators. Longitudinal studies are also useful to assess specific subsectors, and the progress that has been made on decarbonisation and/or revenue generation.

2. Theoretical background

The destination decarbonisation imperative (Gössling and Higham, 2021) remains a considerable challenge, as most of its dimensions remain under researched and outside of policy dialogues. For instance, there is no consensus on tourism system boundaries (the scope of emissions associated with a destination), scale (what does 'net-zero' imply?), responsibilities (who should reduce emissions within the destination?), timelines (when should emission reduction goals have been achieved?), strategy (which prominence should be given to technology innovation, efficiency gains, or behavioural change?), or cost (which investments need to be made?). Considerable complexity is implied in these questions, which also explains the lack of progress on achieving emission reductions (Peeters et al., 2016; Scott and Gössling, 2021).

Under the Paris Agreement, it is countries that have to reduce emissions to net-zero (United Nations, 2015). The timeline set for this is 2050, to have a reasonable chance to stay within global warming guardrails of 1.5°–2 °C, compared to pre-industrial times (IPCC, 2021). Mitigation pathways putting greater emphasis on reducing emissions early will have a greater chance of supporting the UNFCCC objectives and country specific pledges. For tourism, complexity is implied in system boundaries. Should countries be accountable for emissions from aviation or cruises, subsectors of the global economy that are formally a responsibility of International Civil Aviation Organization (ICAO) and World Maritime Organization (WMO)? The questions regarding tourism system boundaries have been raised for a long time (Gössling, 2013), but remain unresolved and contribute to tourism and climate policy incoherence (Scott and Gössling, 2021). More recently, it has been proposed that it is meaningful to calculate emissions in relation to economic value generation, i.e., to use the UN World Tourism Organization's (UNWTO) Tourism Satellite Accounts (TSA) as a basis for comparison of economic performance with emissions (Lenzen et al., 2018). Under this input-output (IO) approach, a destination's economic tourism value can be associated with the environmental impact, for which the destination becomes responsible. This has the added advantage that no emissions remain unaccounted for, and is a practical way forward for destinations to prioritize action on global warming.

The IO method has been used in diverse tourism contexts, including at the global scale (Lenzen et al., 2018), as well as on the scale of individual countries/regions, including Australia (Dwyer et al., 2010), China (Meng et al., 2016; Zhong et al., 2015), Spain (Cadarso et al., 2015, 2016), Germany (UBA, 2020), Japan (Kitamura et al., 2020), Romania (Surugiu et al., 2012), Taiwan (Sun, 2014), and New Zealand (Becken and Patterson, 2006; Sun and Higham, 2021). These studies have provided a number of important insights. For example, a key finding is that globally, tourism is more energy-intense than other economic subsectors, causing emissions of about 1 kg CO_2-equivalent[1] per US$ of final demand, which can be compared to the world economy average of 0.75 kg CO_2 per US$ (Lenzen et al., 2018). The aforementioned national studies similarly confirm that tourism is not an emissions efficient economic sector. Air travel is particularly relevant in contributing to emissions. The share of arrivals by air, together with the average distance flown, both determine a significant share of the overall carbon footprint of a destination, which influences the carbon intensity of the economy. This points at a dilemma in the context of the future development of tourism, as a growing economy (in terms of revenue) faces a greater decarbonisation challenge, as more significant emission reductions have to be achieved per unit of economic value. For example, Gössling and Higham (2021) conclude that the global ratio of emissions to revenue would have to improve to 0.4 kg CO_2 per US$ by 2030 in a linear interpolation to net-zero emissions by 2050.

Additional insights can be gained from national assessments. A study for Germany concludes that tourism accounted for 4.5% (38.5 Mt CO_2) of national CO_2 emissions in 2015 (UBA, 2020). This corresponds to an equivalent of about 307 t CO_2 per million US$, making tourism more carbon intense than the average of the German economy (264 t CO_2 per million US$). Notably, aviation is found to be 14 times more carbon intense than economic sub-sectors on average, at 4151 t CO_2 per million US$, followed by tourism-related shipping at 4004 t CO_2 per million US $. In comparison, accommodation is a significantly more carbon-efficient sub-sector, at 69.7 t CO_2 per million US$, and hence just a quarter of the national average.

This leads to the question of how tourism related emission reductions can be best achieved. Available studies for aviation have suggested that even though technologies to reducing emissions exist in principle, the upscaling and cost of these technologies is prohibitive, requiring political intervention (Gössling et al., 2021). This is also true for the cruise sector (Gössling et al., 2021). Policies will affect ratios of emissions to revenue, for instance by making the transport component of a holiday more expensive, and thus indirectly influencing length-of-stay in positive ways. However, destinations and businesses will profit from more strategic approaches to mitigation, for which it will also be necessary to monitor progress, something tourism remains broadly ill-prepared for (Scott and Gössling, 2021).

Sun and Higham (2021) propose four specific reporting tools to accelerate decarbonisation on the national level, including the (1) overall tourism carbon footprint; (2) emissions per unit of economic value; (3) the speed of decarbonisation as derived from annual measurements; as well as the (4) benchmarking of emissions and value generation in between tourism sub-sectors, or in comparison to other economic sectors of the economy. The analysis of New Zealand reveals that tourism contributed NZ$23.9 billion to the national economy in 2013, at a carbon cost of 9.8 Mt CO_2. Tourism supported 4.4% of the GDP, but it caused 9.2% of national emissions. While overall emissions from tourism have grown between 2007 and 2013, by 0.6 Mt CO_2, tourism revenue growth was significantly faster. CO_2 emissions increased at one third the speed of revenue (Sun and Higham, 2021, p. 6). Yet, tourism is decarbonising at a lower rate than the national economy (2.8%, as compared to 3.7%), mostly because of aviation.

[1] Throughout the text, CO_2 refers to equivalents, i.e. including the combined global warming potential for the six most relevant greenhouse gases carbon dioxide (CO_2), nitrogen dioxide (N_2O), methane (CH_4), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF6). Not considered are the very significant short-lived non-CO_2 warming effects from aviation (Klöwer et al., 2021).

Insights such as these are valuable for the discussion of the dimensions of destination emissions challenge previously outlined, i.e. responsibilities, trajectories, and costs of mitigation.

This study is focused on Norway, a wealthy OECD country that, in terms of tourism spending, is both an important international outbound market as well as a destination. Figures for 2019, the last "normal" tourism before Covid-19 pandemic disruptions, show that tourism grew rapidly, both in terms of international tourism consumption, domestic tourism consumption, as well as in terms of travel by Norwegians abroad (Innovation Norway, 2020). Tourism generated NOK124.9 billion in expenditures in 2019. Norway registered 111 million overnight stays in Norway, with Norwegians accounting for 90% of these overnight stays, often including visits to friends and family or trips to owned cabins (Innovation Norway, 2020). Of interest in the context of this research is that overnight stays include 15.5 million nights spent by Norwegian business travellers, mostly in commercial accommodation. There were also 945,000 international cruise passenger arrivals. Most foreign tourists arrive from Germany (15%), followed by the USA (12%). The share of arrivals from countries outside Europe increased from 11% in 2005 to 24% in 2019. The Norwegians themselves made 18.5 million trips domestically (60% of trips) and abroad (40% of trips).

In a study of emissions from Norway's tourist travel, Grythe and Lopez-Aparicio (2021) suggest that transport CO_2 emissions were 8.5 Mt CO_2 in 2018, out of this 71% related to aviation, and another 21% on maritime transport. As the study focuses on the travel of domestic and international tourists within, from, and to Norway, the system boundary is not comparable to IO studies (Sun et al., 2020; Sun et al., 2019). Yet, there are important insights in regard to distribution, as Grythe and Lopez-Aparicio (2021) find that travel by Norwegians outside Norway causes considerably larger emissions than travel by non-residents in Norway. The difference amounts to 1.6 Mt CO_2 (in 2018), mostly because of trips by Norwegians to destinations such as Spain, Greece, Turkey and Thailand. Grythe and Lopez-Aparicio (2021) highlight the implications for accounting principles for outcomes, as consumer-based calculations would lead to greater responsibilities for mitigation in the global tourism markets.

Developments in tourism and the emissions these cause need to be considered in comparison to national ambitions for decarbonisation. In February 2020, Norway updated its Nationally Determined Contribution (NDC) under the Paris Agreement to reduce emissions by at least 50 per cent and towards 55 per cent compared to 1990 levels by 2030 (UNFCCC, 2020). This represents a "fast" decarbonisation strategy, in the sense that the country will seek to reduce emissions swiftly over the next decade, to then more slowly approach the mid-century target of zero emissions. Tourism has relevance in this objective, as the sector is expected to grow by 37.5%–2030, compared to 2019 (Visit Norway, 2021).

3. Method

3.1. Objectives and analysis

This paper seeks to evaluate, decompose and forecast Norway's tourism development and to assess its implications for national carbon emissions. For this purpose, a national tourism carbon emission inventory is created that details emissions produced by tourism industries (direct emissions), emissions produced by domestic and international suppliers that provide inputs to tourism firms (indirect emissions), and emissions associated with tourism-related private vehicle use. This captures all elements of a complete tourism carbon footprint (CF) (Lenzen et al., 2018). In building upon the national tourism carbon emission inventory, we also compare the economic and environmental trade-off of tourism activities in Norway, benchmark tourism's environmental performance against other sectors in the economy, track the sectoral decarbonisation speed in the last decade, and project tourism emissions to 2030. In particular the latter two aspects are novel in the development of destination-focused carbon inventories.

The calculation of emissions is based on and consistent with the system boundaries in Norway's System of National Accounts. This ensures the comparability of carbon emissions with revenue, and allows for the calculation of tourism's contribution to national greenhouse gas emissions in relative (percentage) and absolute (total emissions) terms. On this basis, an emissions/GDP indicator can be derived, i.e. the ratio of "greenhouse gas emissions per unit of value added (GEVA)" (Randers, 2012). This indicator can be used to compare the emissions efficiency tourism with other economic sectors, and it has relevance for the calculation of the consequences of an expanding tourism sector for the national economy.

Emissions from tourism are influenced by four parameters: total tourism consumption, amount and type of products/services consumed, economic structure (domestic/foreign suppliers), and the energy use pattern of firms (Robaina-Alves et al., 2016; Sun, 2016). Changes in the tourism carbon footprint can be tracked over time by monitoring developments in the four factors, which in turn are linked to average travel distances (long-haul/short-haul market share), local revenue generation, or leakage (Oklevik et al., 2019).

In this paper, a decomposition analysis is carried out to understand how rapidly tourism businesses can decline in emissions through technological and operational improvements, whether changes of economic structure affect the supply chain, how visitor consumption drives emission growth, and whether the energy-intensity of consumption changes over time. Knowledge of these aspects helps to identify barriers to mitigation as well as potentially supportive processes and policy.

More specifically, the analysis can determine whether technology change has contributed to mitigation, and how international trade and the supply chain influence the carbon footprint. This is important because for some subsectors including food or retail, indirect ("embodied") emissions can be higher than those produced by the businesses selling the goods or services (Cadarso et al., 2015; Sun, 2014). The analysis can help to identify products/services or supply chains with lower carbon intensity. Demand factors help understanding how tourism consumption influences emissions, either because of an increase in demand (more consumption) or changes in the energy-intensity of the products consumed.

The decomposition analysis thus serves two major purposes: (1) to understand whether the system decarbonises fast enough to outweigh the additional energy use associated with growth in tourism demand; and (2) to project whether emission reductions are "on track" to lead to a full decarbonisation by 2050, supporting Norway's NDC.

3.2. System boundaries

Tourism is complex, making it important to specify system boundaries and allocation principles to provide valid, consistent and comparable calculations (Gössling, 2013; Sun et al., 2020; Sun et al., 2019). The study adopts the "Statistical Framework for Measuring the Sustainability of Tourism (SF-MST)" recommended by United Nations World Tourism Organization (UNWTO) and United Nations Statistics Division to quantify the impacts of tourism at the national level (UNWTO, 2018). This framework is internationally recognised and comparable across sectors and countries. It is based on tourism satellite accounts (TSA), and links consumption to emissions through the System of Environmental-Economic Accounting (SEEA). Both TSA and SEEA are part of the System of National Accounts, i.e. data is available where these are in use.

Within the TSA framework, the economic value of international aviation is determined based on the economic transactions reported by national carriers and reflected in a country's GDP (UNSD-EUROSTAT-OECD-WTO, 2008). Hence, emissions from national carriers registered in Norway are included in the tourism emission inventory by multiplying total sales generated in all (domestic and international) routes with air transport emission coefficients. This procedure includes emissions of domestic flights and emissions for flying residents and foreign tourists in and out of the country from flights operated by Norwegian Air, Norwegian Air Shuttle, Scandinavian Airlines and Wideroe. For foreign carriers flying to Norway, such as United Airlines and KLM, their economic contribution is not captured in Norway's TSA, and thus their emissions are excluded. Linking international aviation in the TSA to the tourism carbon emission inventory provides a solution to address the long-lasting loophole in overlooking the climate impact of the international flights in developing tourism (Dwyer et al., 2010). This also overcomes the problem implied in the IPCC guideline to calculate emissions associated with international aviation based on the amount of fuel sold in Norway for international flights without differentiating which airline uses the bunker fuel. The IPCC procedure is likely to underestimate the amount fuel used by Norwegian airlines for operating intentional flights (Velzen and Wit, 2000), while also making it impossible to link emissions with revenue.

The system defined as "Norwegian tourism" thus comprises: *Visitor expenditure*, as defined by the Norwegian TSA. This includes travel expenditure as received by businesses in Norway from business travellers, inbound visitors, and domestic tourists (for their domestic journeys and local spending for outbound trips). This covers 11 items on transport, accommodation, food, recreation and shopping purchases. It also includes expenses paid by residents and foreigners for their international flights from and to Norway to airlines registered in Norway. The analysis does however exclude expenditure/emissions of Norwegians in other countries. *Emissions*, this is, direct emissions produced by Norwegian tourism businesses (including emissions of international flights), indirect emissions produced by Norway suppliers, emissions embodied in imports from foreign suppliers, and emissions produced by private vehicle use by tourists.

The single region input-output (SRIO) model is used to determine emissions embedded in the domestic and international supply chain. It is favoured over a multi-regional input-output (MRIO) model for reasons of data availability. Most international MRIO datasets do not include Norway-specific environmental parameters (such as EUROSTAT) or data is not available for the year 2019 (GTAP, EXCIOBASE and WIOD). The use of the SRIO model ensures that the most detailed and current economic and environmental accounts are used, and results are directly comparable to national total carbon emissions and GDP. Emissions associated with imported products/services are estimated using Domestic Production Technology (DTA) assumptions. DTA assumes that imported products/services will be produced using the same technology as those available in the domestic market (Miller and Blair, 2009). It is important to note that this assumption may lead to an underestimation as some of Norway's major trade partners, such as Australia and China, which are more carbon-intensive in their production structures than Norway, as they rely on non-renewable rather than renewable energies (Peters and Hertwich, 2006).

After cross-referencing data sources through multiple Norway governmental agencies, the analysis was carried out for the years of 2007, 2012 and 2019. Due to a restructuring of input-output tables in 2012, the decomposition analysis was only carried out for 2012 and 2019. Norway distinguishes national emissions (Norwegian territory), which accounted for 49 Mt CO_2 in 2020, and emissions from Norwegian economic activity (66 Mt CO_2 in 2020). This paper is focused on economic activity, and hence uses the latter statistic that also includes aviation and shipping.

3.3. Model

A single region input-output model was constructed for Norway, showing results for 65 industries. Calculations are based on sector-specific emissions factors per million dollar output (Statistic Norway, 2021a). This is expressed as a ratio of million NOK per ton CO_{2e} (the latter representative of all six major greenhouse gases). Non-CO_2 effects from aviation are not included, underestimating the importance of aviation for global warming (Klöwer et al., 2021). Following the calculation process established in Sun and Higham (2021), emissions produced by Norwegian businesses and foreign producers were derived by multiplying TSA visitor expenditure with direct and indirect carbon emissions multipliers.

Emissions from tourism-related private motor vehicle use are estimated separately from the input-output model. The process first estimates visitor expenditure on petrol, which is then converted to total litres of gasoline used by all tourists based on the average price per litre in Norway (Statistic Norway, 2021b). The next step is to use the fuel emission factors to calculate carbon dioxide equivalent values based on the amount of fuel that is consumed by tourists.

The last step compares tourism carbon emissions between 2012 and 2019 to evaluate whether and how fast tourism decarbonised, and whether the tourism carbon footprint increases in proportion to consumption. We perform a structural decomposition analysis (SDA), using the formula as presented in Sun and Higham (2021), to allocate the difference of carbon footprint in regard to four factors: total visitor consumption, items purchased, emissions per dollar output, and the linkage across sectors and foreign producers (economic structure).

4. Results

4.1. Carbon intensities

In 2019, tourism contributed NOK194 billion in visitor expenditure to the national economy (Statistic Norway, 2021b). Norwegian household leisure expenditure contributes to approximately half of this (55%), followed by inbound visitors (31%) and domestic business travel (14%). Air transport is the most important revenue-generating subsector (17%), followed by food and beverages (13%), travel agencies (10%) and accommodation (10%).

Revenues of NOK194 billion are matched by an estimated 4.379 Mt of direct CO_2 emissions, to which private vehicle use adds 1.826 Mt CO_2 (see Table 1). Emissions from national suppliers add 1.927 Mt. In total, tourism activities are directly responsible for 8.132 Mt CO_2 in Norway. The consideration of emissions embodied in imports adds 2.067 Mt. This results in an overall global climate impact of about 10.199 Mt CO_2, of which 43% derive from tourism businesses in the country, 18% from vehicle use, 19% from the domestic suppliers, and 20% from international imports.

In terms of contribution by visitor segments, domestic leisure tourism accounts for half (53%) of CO_2 emissions, followed by inbound tourism (30%), and domestic business travel (17%). The performance per dollar output, however, reveals a different ranking. Business travel turns out to be the most carbon intensive segment, producing 44.3 t CO_2 per million NOK revenue, two times higher than the other two groups (around 18–19 t CO_2 per million NOK). The extensive use of aviation services among business travellers drives up the carbon intensity, reflected in their 40% per trip expenditure on this item. In contrast, less than 15% of the travel budget of domestic and inbound tourists falls on aviation services.

More generally, results show that air transport is the most critical emission sub-sector. It accounts for 75% of the direct CO_2 emissions that are produced by tourism. This is followed by marine transport (8%) and land transport (5%). Transportation is responsible for almost 90% of direct tourism emissions among businesses. Another critical element of transportation is the use of private vehicles for travel. Private vehicle emissions of 1.826 Mt are three times larger than the combined emissions associated with marine and land transport, and about the size of all indirect tourism emissions produced by the domestic supply chain. In contrast, the accommodation and restaurant sector produce less than 1% of the direct tourism business emissions, though they account for 23.7% of spending.

When considering direct and indirect emissions, 50% of tourism emissions are a result of aviation, followed by food (12%),

Table 1
The Norwegian tourism carbon emissions, 2019.

Spending and emissions	Inbound visitors	Domestic visitors (leisure)	Domestic visitors (business)	Total tourists	Percent of direct emissions	Percent of total emissions
Consumption expenditures (NOK million)	59,377	107,226	27,296	193,899		
Percentage	31%	55%	14%	100%		
Emissions (Mt)						
1. Total direct emissions (=1.1 + 1.2)	1.926	3.071	1.208	6.205		61%
1.1 Direct carbon emissions from sectors	1.076	2.094	1.208	4.379	100%	43%
Accommodation & food	0.024	0.021	0.014	0.059	1%	
Rail & road transport services	0.035	0.118	0.045	0.197	5%	
Water transport services	0.111	0.193	0.057	0.362	8%	
Air transport services	0.691	1.501	1.090	3.282	75%	
Transport equipment rental services	0.002	0.001	0.001	0.004	0%	
Travel agency operator services	0.000	0.012	0.001	0.014	0%	
Cultural services	0.001	0.001	0	0.002	0%	
Sports and recreational services	0.001	0.001	0	0.002	0%	
Tourism consumption of other products	0.211	0.246	0	0.457	10%	
1.2 Emissions from private motor vehicle	0.849	0.977	0	1.826		18%
2. Indirect emissions	0.561	1.157	0.031	1.927		19%
3. Embodied emissions	0.557	1.169	0.051	2.067		20%
4. Total emissions in Norway (=1 + 2)	2.487	4.229	1.239	8.132		80%
5. Total emissions in Norway and other countries (=1 + 2+3)	3.044	5.398	1.290	10.199		100%
Percent	30%	53%	17%	100%		
Direct emission/dollar ratio (t CO_2/million NOK)	18.1	19.5	44.3	22.6		

pharmaceutical products (6%), and sea transport (5%). This is consistent with the global finding that once the supply chain effects are considered, the climate impact of food and shopping become more relevant (Lenzen et al., 2018).

Data also reveals that there are high-yield, low-emissions and low-yield, high-emissions segments. Non-transport usually belongs to the former, while transport (air, sea, land) includes the major emission components. Results confirm findings in other countries. For example, aviation accounts for 53% of tourism emissions in New Zealand, 49% in Australia, 38% in Taiwan, and 37% in Spain (Cadarso et al., 2015; Dwyer et al., 2010; Sun, 2014; Sun and Higham, 2021).

4.2. Inter-sectorial comparison

Results can be compared with other sectors of the national economy. Here, the comparison involves direct economic with direct emissions, as indirect environmental effects for other economic sectors are unknown. Any sector's performance is also divided into tourism and non-tourism components to avoid double counting. For example, the total revenue of the transport sector was 277 billion in 2019, which is divided into (1) tourism-related transport (NOK43 billion, included in tourism), and (2) non-tourism transport (NOK234 billion).

Economically, tourism contributes 3.6% to the national GDP and 7.0% of full-time employment in 2019 (Statistic Norway, 2021b). Most tourism jobs exist in the food and beverage sectors (29%), followed by road transport (17%) and cultural activities (15%) (Statistic Norway, 2021b). Environmentally, tourism emits 8.8% of total national carbon emissions (see Table 2). Tourism produces more than twice the emissions per million NOK dollar revenue (22.58 t CO_2) than the national average (10.76 tonnes).

To further understand tourism's performance in comparison to the 35 other economic sectors in Norway (Statistic Norway, 2021a), four indicators are used, revenue, employment, emissions, and the emission intensity per million NOK output. As shown in Table 3, tourism ranks 13th in terms of production value, 6th for employment, 5th in emissions, and 8th in emission intensity.

These interrelationships are illustrated in Fig. 1, which shows the cumulative importance of different economic sectors, when ranked by emission intensity. More than two thirds (70.6%) of the economic value in Norway are produced by economic sectors that have very low emission intensities of up to 4.5 t CO_2 per million NOK. Together, these 23 sectors account for just 8.1% of overall total emissions. The graph also illustrates that improvements in emission-intensity are specifically relevant in five sectors with very high emission intensities (ocean transport, agriculture and forestry, basic metals, refined petroleum, fishing and aquaculture). Tourism is doing better than these sectors, but it also accounts for a larger share of total national emissions. The combination of comparably high emission intensity and large contribution to overall emissions suggests that tourism is a highly relevant sector for net-zero carbon management, also because of the country's growth plans in tourism (Visit Norway, 2021).

4.3. Changes in emissions over time, 2007–2019

Between 2007 and 2019, tourism expenditure grew from NOK116 billion to NOK194 billion (67%), while tourism's direct emissions increased from 4.2 Mt to 6.2 Mt (46%) (see Table 4). Tourism's contribution to the national economy was stable at about 3% of national GDP, but the sector's share in national greenhouse gas emissions increased from 5.8% to 8.8%. This is a reflection on the overall decarbonisation of

Table 2
Benchmarking tourism against the whole economy in Norway, 2019.

Economic and environmental performance	The tourism sector	Norway	Tourism share
GDP (NOK billion)	129.9	3568.5	3.6%
Employment (Full-time equivalents, 1000's)	171	2455	7.0%
Emissions(Mt)	6.205	70.883	8.8%
Emissions/revenue ratio[a] (t CO_2/million NOK)	22.58[a]	10.76	

[a] Private vehicle use does not generate revenue. To ensure consistency, we exclude emissions of private vehicle use.

Table 3
Ranking of tourism, based on four indicators.

Revenue (billion NOK)		Employment (000's)		Total emissions (Mt)		Emission intensity (t CO_2/mill NOK)	
1. Construction	651	1. Health and social work	572	1. Oil and gas extraction	14.895	1.Ocean transport	121.2
2. Oil and gas extraction	630	2. Wholesale and retail trade	359	2. Ocean transport (non-tourism)	14.133	2. Agriculture and forestry	119.9
3. Wholesale and retail trade	465	3. Construction	247	3. Agriculture and forestry	5.988	3. Basic metals	55.3
4. Health and social work	464	4. Education	222	4. Land and air transport (non-tourism)	5.175	4. Refined petroleum and chemicals	34.0
5. Public administration	373	5. Public administration	221	5. Tourism	**4.379**	5. Fishing and aquaculture	33.7
Tourism (13th)	**194**	**Tourism (6th)**	**171**			**Tourism (8th)**	**22.6**
						National average	10.8

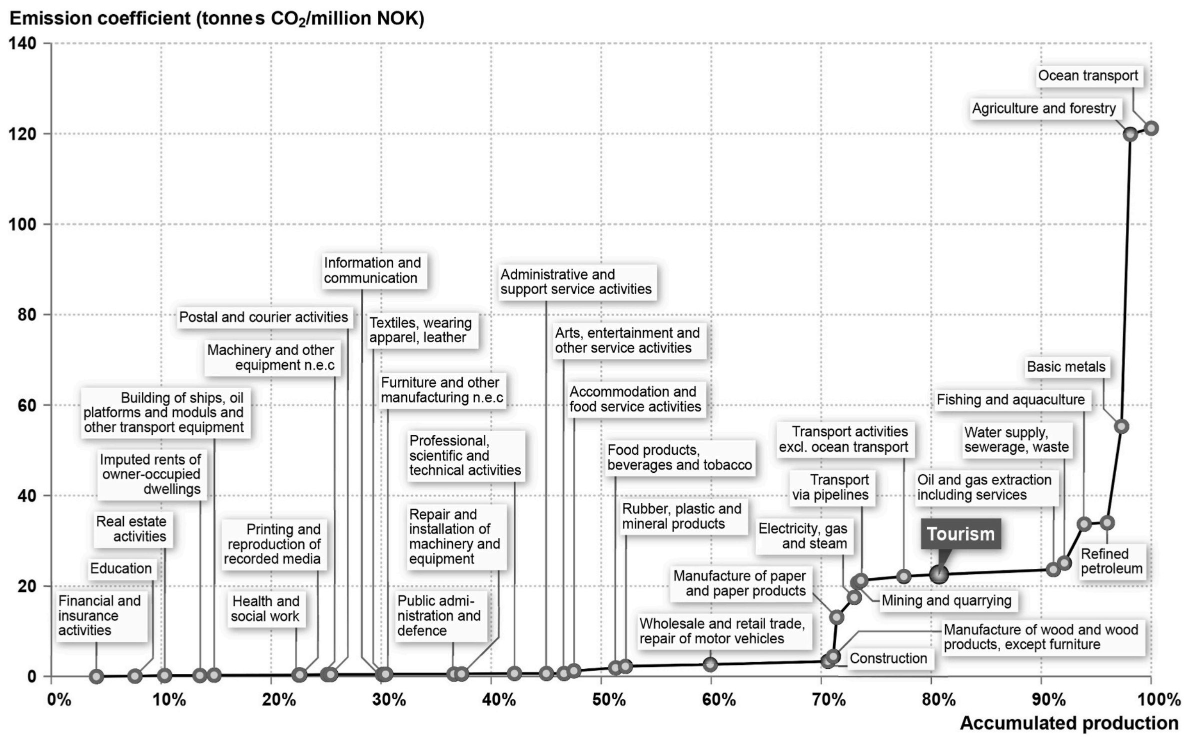

Fig. 1. Emission intensity and contribution to GDP, Norway, 2019.

Table 4
Economic and environmental performance of tourism in Norway, 2007–2019.

	Production (NOK billion)	Emissions from economic activities (Mt)	Emission intensity (tonnes CO_2/ mill NOK)
Norway			
2007	3911	72.810	16.87
2012	4838	68.815	12.85
2019	6060	70.883	10.76
Average annual change rate	3.7%	−0.2%	−3.7%
Tourism			
2007	116	4.246	24.39
2012	137	4.713	24.84
2019	194	6.205	22.58
Average annual change rate	4.4%	3.2%	−0.6%
Percent/ratio			
2007	3.0%	5.8%	1.45
2012	2.8%	6.8%	1.93
2019	3.2%	8.8%	2.10

the Norwegian economy, in which tourism lacks behind, as the sector's emission intensity rose from 1.45 times the national average in 2007 to 2.1 times the average in 2019. This shows that other economic sectors are decarbonising much faster than tourism.

Economic growth in Norway (3.7% per year) is offset by the improvement of its own carbon intensity (3.7% per year), with a reduction of greenhouse gas emissions by 0.2% annually (2007–2019). In comparison, the efficiency gain of tourism was 0.6% per year, leading to a growth in emissions by 3.2% per year. The increasing carbon intensity of the aviation sector is the main factor in this. Air transport produced 63.5 tonnes CO_2/mill NOK in 2007, and 103.8 tonnes CO_2/mill NOK in 2019 (Statistic Norway, 2021a). As a result of this change in emission intensities (4.2% annually), tourism-related aviation emissions have risen from 1.6 Mt CO_2 to 3.3 Mt CO_2, or 6.3% annually in total emissions. Aviation is responsible for 80% of the net increase of tourism carbon emissions from 2007 to 2019, and tourism is again responsible for the comparably low rate of decarbonisation in the country. Over time, it will become increasingly difficult for Norway to decarbonise if tourism, and particular aviation, continues to grow as over the past decade.

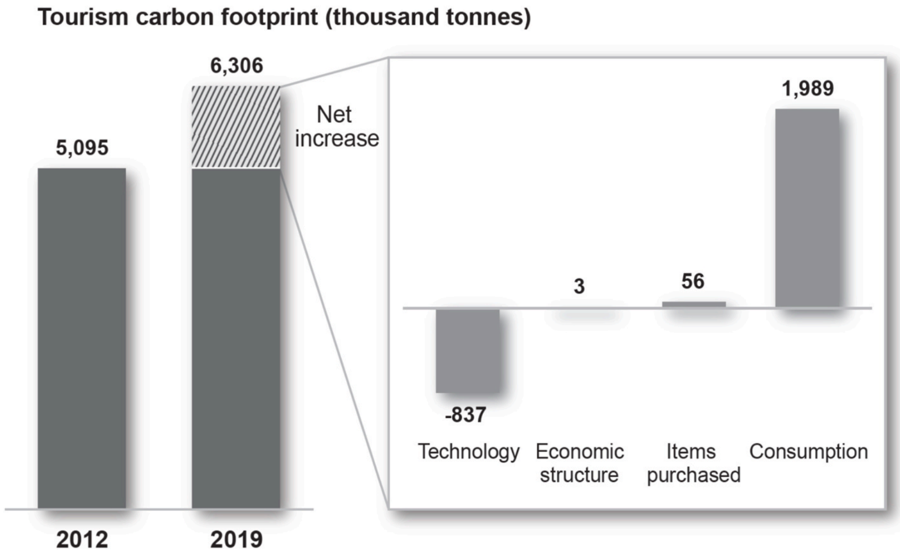

Fig. 2. Decomposition analysis of tourism carbon emissions, 2012–2019.

4.4. Decomposing the global tourism carbon emissions of Norway, 2012–2019

The overall climate impact of tourism (direct, indirect and imported emissions) has increased from 7.154 Mt to 8.373 Mt (+17%) between 2012 and 2019.[2] The net increase of 1.219 Mt can be broken down into four components (see Fig. 2):

- Total consumption: An increase in tourism spending by 22% between 2012 and 2019 would have increased tourism emissions by 1.989 Mt CO_2, assuming that energy use and business operation remain the same as those in 2012.
- Items purchased: There has been an increase in spending on marine and air transport services, as well as on recreational activities. The former is highly carbon intensive, but not the latter. Changes in spending have outbalanced each other, causing an increase of 0.056 Mt CO_2.
- Economic structure: There is a trend towards using a greater share of locally produced, but more energy intensive items, including agricultural products, fish, souvenirs, and air transport. The reliance on foreign producers of these same ingredients/services declines, leading to a smaller embodied footprint, counterbalanced by the increase in consumption of more energy intense items. This causes an additional 0.003 Mt CO_2.
- Technology: The intensity effect measures how much energy firms have to use in order to produce one dollar of economic output. Both Norway and global suppliers have become more efficient or introduced new technologies, reducing the overall growth in emissions from added consumption by 0.837 Mt CO_2.

The decomposition analysis shows that the increase in consumption is partially offset by technology improvement, changes in economic structure, and changes in travel patterns. These include purchases of domestic products, an increase in recreational activities, and efficiency gains likely arising out of various forms of low-carbon technology adoption and energy saving initiatives. Together, these have offset 40% of the additional emissions associated with the growth in consumption. Norway's tourism carbon emissions (direct, indirect and imported) expanded at approximately half the speed of the tourism expenditure. Overall, these results suggest that decarbonisation in absolute terms, and at rates necessary to meet the Paris Agreement's objectives, will be impossible if energy-intense tourism consumption continues to grow.

4.5. Emissions in 2030

Based on a *business-as-usual* scenario, tourism emissions can be forecast for the next decade. This builds upon the assumptions that the tourism system will rebound post-COVID and return to its 4.4% growth rate from 2023 onwards. Efficiency gains will continue as observed between 2012 and 2019. On this basis, direct tourism emissions in Norway will likely grow to 8.247 Mt by 2030, i.e. grow by 30% over 2019. This is in stark contrast to the country's Nationally Determined Contributions, as Norway has committed to half its emissions by 2030, compared to 1990 (Ministry of Climate and Environment, 2021). If applied to total national emissions, including aviation, this corresponds to an amount of 33 Mt CO_2 that have to be avoided by 2030. Continued growth in tourism emissions will question this ambition, and if Norway manages to decarbonise the rest of its economy, exempting in particular aviation for reasons of cost and lack of alternative technologies, tourism will be the most relevant emission sector by 2030, contributing to about a quarter of total national emissions.

5. Discussion

Findings provide several insights of relevance for destinations. The most important is that tourism is a highly emission-intense sector because of aviation. This has been shown in numerous earlier studies (Becken and Patterson, 2006; Eijgelaar et al., 2017; Gössling et al., 2005; UNSD-EUROSTAT-OECD-WTO, 2008). In Germany, the average carbon intensity per US$ of revenue in tourism is 0.31 kg CO_2; for aviation, it is 14 times higher, at 4.15 kg CO_2 per US$ (UBA, 2020). In New Zealand, the tourism economy is more efficient than in Germany, at 0.24 kg CO_2 per US$ of revenue, and 0.87 kg CO_2 per US$ of revenue for aviation. This study suggests an emission intensity of 0.19 kg CO_2 per US$ of revenue for Norway, the lowest yet identified in any study (Cadarso et al., 2015; Meng et al., 2016; Sun, 2014; Sun and Higham, 2021), and 30% more carbon efficient than the New Zealand tourism economy. However, aviation as a subsector emits 0.89 kg CO_2 per US$, or about 5 times the tourism economy average. These results single out aviation in regard to i) its importance in overall tourism emissions (relative and total); ii) its role in making tourism a sector that is highly carbon intense in comparison to other economic sectors; and iii) its carbon intensity in

[2] The decomposition analysis is used to analyze changes of emissions from economic activities, and emissions from the private vehicles are excluded here.

relation to other tourism sub-sectors. Per unit of revenue, few other economic subsectors perform as poorly as air transport. These findings also need to be viewed in light of the omission of non-CO_2 warming caused by aviation (Klöwer et al., 2021). Including these effects further reduces aviation's eco-efficiency.

It follows that from both environmental and economic points of view, aviation needs to be considered the most critical subsector in any destination's tourism economy. In Norway, this is a specific concern, in that the longitudinal analysis has revealed that aviation is becoming rapidly more carbon intense. Each year, the carbon investment needed to derive a unit of economic value has been growing by 4.2%. This emphasizes the relevance of destination management concepts focused on demarketing long-haul markets, substituting air travel, and introducing low-carbon propulsion. Results also highlight the relevance of management approaches seeking to increase average length of stay and favouring revenue optimisation over growth in arrivals (Oklevik et al., 2019). Domestically, policies that subsidise air transport need to be reconsidered; an issue that has relevance in Norway, where MICE travel is a norm (Høyer, 2000) and where many remote hotels depend on this travel segment. As the results suggest, any reduction in business travel will improve the tourism sector's carbon intensity, in support of post-COVID trends that have seen a decline in this sector. On the positive side, results show that accommodation-related emissions can be reduced to near zero by sourcing renewable energy. In Norway, accommodation generates 17% of the tourism value, but only 1% of emissions. To switch to renewable energy is an option for businesses in virtually any country, and renewable energy is now cheaper to install than any other electricity source (Ourworldindata, 2020).

As findings highlight, the national tourism carbon intensity is 2.1 higher than the national average, and per unit of revenue, tourism decarbonises much slower (0.6% per year) than the whole economy (3.7% per year). It will take significant action to decarbonise the national tourism system, and net-zero will not be achievable without a focus on aviation. The current outlook is that by 2030, tourism will account for one quarter of national emissions. Against this background, it is paramount to calculate decarbonisation rates in carbon intensity and emissions in relation to economic growth. To achieve a 90% decarbonisation by mid-century (of 2019 emissions), the national annual decarbonisation rate would have to be 7.4% per year, and carbon intensity has to improve by 10.5% per year for the economy and 11.3% per year for tourism (Table 5). Achieving higher decarbonisation goals, of 95% or 99%, would require even more drastic decarbonisation rates of up to 14.2% per year. These high rates are necessary, as economic output triples to 2050, illustrating the challenge of decarbonisation in a scenario of continued economic growth.

6. Conclusions

This paper advances the issue of national decarbonisation by linking tourism with the wider economy. There are many tourism-dependent countries in the world, and Norway is no exception. Due to its peripheral location in Europe, and the distances covered by many international travellers to get to Norway, aviation plays a significant role in the national economy. Several findings have relevance in this regard. First of all, in regard to boundaries, the study shows the importance of including aviation in national greenhouse gas inventories. To treat this sector as "international", with responsibility for emissions assigned to ICAO, obscures its importance in both economic and environmental terms. The input-output analysis used in this paper also resolves the question as to who should be accountable for emissions, as economic gains are linked to emissions. If more destinations calculated emissions on an IO basis, all would be accounted for, and responsibilities assigned. This also highlights the necessity for policymakers to broaden the scope of national ambitions to embrace this responsibility. In reality, the antecedents of such approaches are already established, as Norway has, for instance, introduced a feed-in quota of sustainable alternative fuels for aviation in 2020 (Regjeringen, 2021).

There is no shortage of national pledges for decarbonisation. Whether these pledges can be met has central relevance for ambitions of the international community to meet the Paris Agreement objectives. The analysis for Norway illustrates the importance of assessing progress on mitigation through integrated environmental-economic analyses that illustrate the decarbonisation speed, differences between economic sectors, and the importance of specific activities that increase emissions, such as continued growth in aviation. This data can be used to make strategic decisions for significantly reducing emissions to 2030, and to plan for net-zero emissions in 2050. For now, there is no consensus what "net zero" may imply, but it would seem prudent for countries to limit emissions to the degree possible.

As this research shows, Norway makes considerable progress on decarbonisation per unit of economic value, but given the country's overall economic growth, the speed of decarbonisation, at 0.2% per year, is hugely insufficient to meet national decarbonisation commitments. For example, Norway's interim goal of reducing emissions by at least 50% by 2030, compared to 1990, is impossible to achieve under this scenario. An integration of net-zero goals over 30 years would require the economy to decarbonise at a speed at least 30 times greater than the current trend, if growth rates are maintained. This also implies the technology improvement (proxy through carbon intensity) has to be expedited from the current 3.7% per year to 10.5% for the next 30 years. Notably, this would represent the 90% emission reduction scenario, not full decarbonisation. The study emphasizes the importance of defining credible emission reduction goals that can realistically be met, and illustrates at the same time the impossibility of achieving net-zero emissions under scenarios of continued growth in emission-intense subsectors. Countries need to understand these complexities in order to present reliable and credible decarbonisation strategies, and inform policy dialogues on a just transition. This will require further work, for instance in regard to legislation and policies, cost assessments, technology upscaling, as well as the more challenging questions of changes in the tourism system that will economically affect specific sectors and businesses.

In concluding this paper, it is acknowledged that the I/O model has shortcomings, as implied in the assumptions made for emission factors, of linear future growth, or constant prices. As the Ukraine war beginning in February 2022 illustrates, systems are dynamic and the future is

Table 5
Decarbonisation rates to net-zero under continued economic growth.

	Norway output (NOK billion)	Tourism output (NOK billion)	National CO_2 (Mt)	Tourism CO_2 (Mt)	Annual national decarbonisation rate on carbon intensity	Annual tourism decarbonisation rate on carbon intensity	Annual national decarbonisation rate on emissions	Annual tourism decarbonisation rate on emissions
2019	6,060	194	70.883	6.205				
Projected to 2050								
90% emission reduction	18,102	707	7.088	0.620	10.5%	11.3%	7.4%	7.4%
95% emission reduction	18,102	707	3.544	0.310	12.5%	13.3%	9.5%	9.5%
99% emission reduction	18,102	707	0.709	0.062	17.1%	17.9%	14.2%	14.2%

ultimately uncertain. This research also highlights various research needs. For example, it is desirable to conduct I/O calculations for a range of countries, and to compare these. Any such comparison is likely to reveal considerable differences between countries, but it will also yield relevant insights for decarbonisation. Future research may also discern the effects of COVID-19 on the Norwegian tourism economy, or the Ukraine war.

CRediT authorship contribution statement

Ya-Yen Sun: Conceptualization, analysis, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Stefan Gössling:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Leif E. Hem:** Writing – review & editing. **Nina M. Iversen:** Writing – review & editing. **Hans Jakob Walnum:** Conceptualization, Writing – review & editing. **Daniel Scott:** Writing – review & editing. **Ove Oklevik:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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