

On track to net-zero? Large tourism enterprises and climate change

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ABSTRACT

Much recent research on climate change mitigation has focused on carbon intensities, i.e. emissions per unit of economic value, to better understand interrelationships of decarbonization with value. This paper studies large tourism enterprises, which account for a large share of tourism's emissions. Based on annual reports, the paper evaluates greenhouse gas emission and revenue interrelationships for a total of $n = 29$ large tourism companies including airlines, cruise lines and accommodation businesses. Together, these companies represent about 13% (365 Mt CO₂) of global tourism emissions, generating revenues of US\$477 billion (in 2019). The paper tracks their total emissions and emission intensities over the period 2015–2019, revealing that large tourism firms are not on track to net-zero. Results show considerable differences in emission intensities between the three tourism subsectors and between individual firms within the subsectors. These findings are discussed against emission reduction needs to mid-century. There is strong evidence that continued growth at industry's expected rates represents an insurmountable barrier to net-zero, contradicting industry narratives of progressively and successfully engaging with climate change mitigation.

1. Introduction

Tourism is an emission-intense economic sector that makes considerable contributions to global warming (Lenzen et al., 2018). High growth rates and interrelated technology-cost barriers for aviation and cruises make tourism particularly difficult to decarbonize (Gössling et al., 2023). The expectation is thus that total emissions will grow, not decline. As tourism generates significant economic and employment benefits (OECD, 2022), it is important to understand interrelationships of energy use/emissions and value generation to identify strategies for decarbonization that are not economically disruptive. Emission intensities have been proposed as a way of combining an economic and environmental perspective (e.g. Gössling et al., 2005; Sun et al., 2022). The use of such indicators has also become more common in industry. For example, the World Travel & Tourism Council recently published global GDP to emission ratios for tourism (WTTC & Oxford Economics, 2022), while the Norwegian Hospitality Association developed “per Norwegian crown” CO₂-footprints for different tourism nationalities and traveller types to concentrate marketing efforts (DN, 2019).

Most academic studies to date have focused on emissions in relation to economic value generation at the national scale (e.g. Cadarso et al.,

2015; Sun et al., 2022; Sun & Higham, 2021). Research at the company level has received considerably less attention, specifically in the context of large firms. Yet, data recently published by the World Bank (2023) suggests that a limited number of multinational enterprises (MNEs) account for significant share of global emissions. For example, three companies, Royal Dutch Shell, Coal India and Gazprom, each emit in excess of 1 Gt CO₂. Cumulatively, they account for 3.87 Gt CO₂ (scope 1–3), representing more than 10% of global emissions of 36.5 Gt CO₂ (IEA, 2023a, pp. 1900–2022). The ten largest MNEs emit 20% of global CO₂ emissions, and the biggest 60 more than half of the global total (World Bank, 2023). This underscores the role of large businesses in contributing to climate change, including many that are tourism firms, such as aircraft manufacturers Airbus and Boeing, or airlines including United Airlines, Delta Airlines, France-KLM, and Qantas (ibid.). While not listed by the World Bank, large tourism enterprises also include hotel chains and cruise lines.

Indicators focusing on emissions in relation to economic value generation can be used to understand the carbon intensity of different economic sectors, or to benchmark the carbon intensity of businesses within specific subsectors. They can also be used, on the national or company level, as reporting tools, and as a means to monitor progress on

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net-zero goals. Indicators help assess risks for carbon-intense sectors as a result of changing energy costs or carbon taxes, or to identify opportunities for economic optimization. Against this background of multiple determinations, the purpose of this paper is to assess developments in carbon intensities of large tourism firms, and to discuss the implications for climate change.

2. Background

2.1. Tourism and climate change

Global greenhouse gas emissions from energy combustion and industrial processes amounted to 36.5 Gt CO₂ in 2021 (IEA, 2023a, pp. 1900–2022). To limit global warming to 1.5 °C and a maximum of 2 °C, the upper critical threshold defined in the Paris Agreement (UNFCCC, 2018), emissions have to be reduced to “net-zero” by 2050 (also defined as “climate neutrality” by the European Commission, 2022). To achieve this, all economic sectors have to decarbonize, as carbon removal strategies to compensate unavoidable emissions remain uncertain and risky, technologically difficult and potentially expensive (IPCC, 2022a). The IPCC estimates that to stay within 1.5 °C, a decarbonization rate of almost 8% per year is necessary between 2020 and 2050, and 3.5% in a 2 °C scenario (IPCC, 2022b, p. 12). As global warming is determined by the “remaining carbon budget”, i.e. the amount of carbon that can still be emitted before specific temperature thresholds are reached, the IPCC has pointed out that it is necessary to make deeper cuts in emissions in the near-term future. Remaining carbon budgets for limiting global warming to 1.5 °C, 1.7 °C and 2.0 °C are approximately 400 Gt CO₂, 700 Gt CO₂ and 1150 Gt CO₂ (67% chance; IPCC, 2021: 29). Fig. 1 shows the development of CO₂ emissions over time, and illustrates the steep reductions necessary in the immediate future.

Tourism is responsible for 8% of global warming in 2013, or an estimated 2.9 Gt CO₂ per year (scope 1–2; Lenzen et al., 2018). Even if tourism manages to stabilize its emissions under continued growth scenarios, it would deplete its “share” of the global carbon budget for the more desirable 1.5 °C goal (40 Gt CO₂) in less than ten years (Gössling et al., 2023). This is an optimistic scenario, as aviation - one of tourism’s most important subsectors -, has grown by a factor 6.8 between 1960 and 2018, to a total of about one Gt CO₂ per year (Lee et al., 2021). Further strong growth is expected for all of tourism, with air transport emissions to grow at a rate of 3% per year, and 5% per year for other tourism related industries (WTTTC-UNEP-UNFCCC, 2021). Such growth rates would make it necessary to decarbonize (to improve emission intensities) at rates of more than 10% per year. There is thus a considerable, if not unresolvable challenge for tourism to reduce its total

emissions under scenarios of continued growth.

2.2. Economic-environmental indicators

Indicators comparing economic and environmental outcomes have been in use for some time to evaluate efficiencies, to develop benchmarks, or to assess the outcomes of consumption. For example, in global contexts, distributional aspects of energy use have received considerable attention in the context of high-emitter assessments (Chancel, 2022). Tourism consumption has important roles in high per capita emissions (Barros & Wilk, 2021). In tourism, emission intensities have been calculated to understand climate implications of value generation at the global level, also in comparison to other economic sectors (Lenzen et al., 2018); to assess differences in the carbon-intensity of destinations (Gössling et al., 2005); or to evaluate tourism emissions, and in relation to other national economic sectors. These latter studies have been carried out for China (Meng et al., 2016), New Zealand (Sun & Higham, 2021), Norway (Sun et al., 2022), Portugal (Robaina-Alves et al., 2016), Spain (Cadarsó et al., 2015), or Taiwan (Sun, 2016).

The use of integrated environmental-economic indicators makes it necessary to determine comparable system boundaries. In tourism, economic output is measured in Tourism Satellite Accounts, which can be combined with environmentally extended input-output modelling (EEIO) to convert consumption into environmental impacts. This approach was used on a global scale to assess emission efficiencies for tourism, which Lenzen et al. (2018: 524) put at “around 1 kg CO₂e per dollar of final demand” in 2013, and hence significantly higher than the global average of 0.75 kg CO₂e per US\$”. Lenzen et al. (2018) concluded that “Growth in tourism-related expenditure is therefore a stronger accelerator of emissions than growth in manufacturing, construction or services provision” (p. 524).

As mitigation policies are implemented at the country level, national assessments represent the most important level of analysis. Here, the measurement of direct and indirect emissions associated with tourism consumption from domestic, inbound and outbound activities within a country is a suitable approach for calculations that serve as a basis for climate governance. International air transport emissions can be included in this accounting method under the airline residence principle, i.e. airlines registered in a country. Where longitudinal data is available, this allows for assessments of progress on decarbonization, as well as the identification of carbon-intense subsectors (Sun et al., 2022). Data can also be used for comparison. National studies have so far revealed that aviation appears to always be the most carbon-intense tourism subsector (Meng et al., 2016; Robaina-Alves et al., 2016; Sun, 2016; Sun et al., 2022; Sun & Higham, 2021). For example, in New

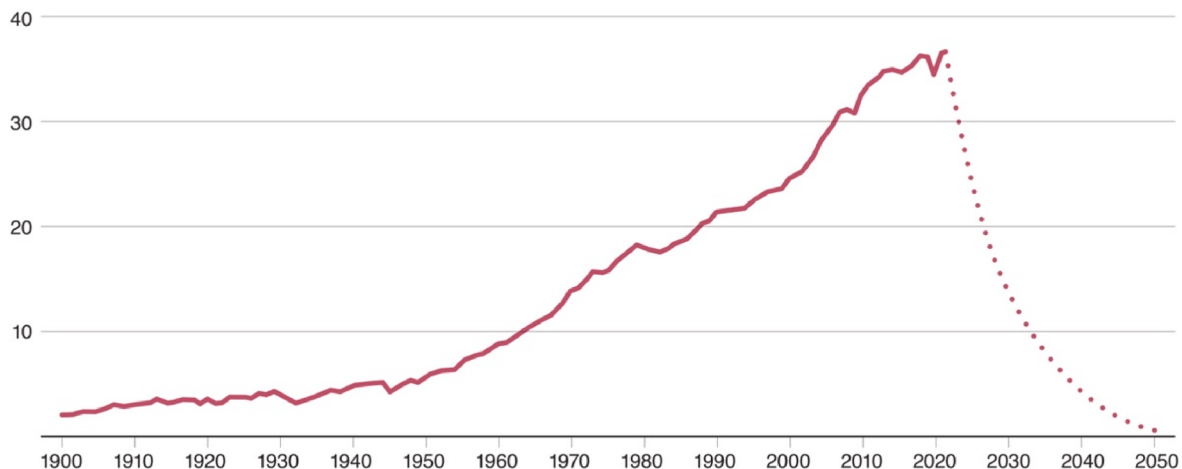


Fig. 1. CO₂ emission growth and necessary decarbonization to 2050.
Source: based on IEA (2023a), IPCC (2021)

Zealand, tourism is 0.24 kg CO₂ per US\$ of revenue, and aviation 0.87 kg CO₂ per US\$ (Sun & Higham, 2021). In Norway, the value is 0.19 kg CO₂ per US\$ of revenue for tourism, and 0.89 kg CO₂ per US\$ for aviation (Sun et al., 2022). While these countries thus perform better than the global tourism economy average, aviation has significantly worse carbon intensities and drives up total tourism emissions (Sun et al., 2022). This does not include (additional) non-CO₂ warming effects (Lee et al., 2021).

Results also have relevance for the discussion of national decarbonization strategies and the role of tourism in these strategies. For instance, findings for Norway (Sun et al., 2022) suggest that tourism contributed 3.6% of GDP and causing 8.8% of CO₂ emissions (in 2019). While the Norwegian economy reduced total emissions by 0.2% per year between 2007 and 2019, direct tourism emissions increased by 3.2% per year in this period. This was mostly due to air transport growth, which accounted for 80% of the observed emissions growth, while accommodation is largely free of emissions due to the use of electricity from renewable sources. These findings underscore that under scenarios of expected economic growth, the Norwegian economy would have to decarbonize 30 times faster to stay on track to net-zero by mid-century. The example illustrates that growth driven by tourism – in Norway mostly air transport – can contradict net-zero ambitions. This points to the importance of better understanding the role of individual firms in decarbonization efforts.

2.3. Emissions from global tourism companies

Under the Paris Agreement (UNFCCC, 2018), responsibilities for reducing emissions are with countries, which pass on this responsibility to companies. For example, the European Union seeks to cut emissions by 55% by 2030, compared to 1990 levels, and to become “climate neutral” by mid-century (European Commission, 2022). Notably, the European Union has included aviation in their Nationally Determined Contributions (NDCs), mandating a 5% sustainable aviation fuel obligation to 2030 (European Commission, 2021). Aviation is also included in the EU Emission Trading Scheme (European Commission, 2023). Countries such as Austria, Germany, Sweden, and the Netherlands have also established national tax regimes for aviation (European Commission, 2021). However, aviation emissions are only partially covered under these policies, and current policies are not aligned with net-zero goals. Outside the EU, for example, aviation bunker fuels used for international operations are to be treated through the International Civil Aviation Organization (ICAO), though it is recognized that ICAO’s emission reduction scheme, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), is neither credibly advancing climate neutrality, nor supporting a transition to alternative propulsion including new fuels (Lyle, 2018). For shipping, the International Maritime Organization (IMO2020) has not defined an emission reduction goal that is compatible with decarbonization at 2 °C, as the organization envisages to only half emissions from shipping by 2050 (Joung et al., 2020).

A key question thus remains how individual companies – specifically air transport and cruises – will address climate change, given the inconsistency and inadequacy of international, regional, and national policy approaches to advance net-zero goals. To reach net-zero, all companies will have to avoid a large share of emissions and neutralize any residual emissions from 2050 onwards (SBT 2023). To plan for net-zero futures, companies consequently will need to understand and manage their emissions. However, a review of 428 firms considered “potential frontrunners in committing to climate action in the sector” concluded that only 34% measured emissions and even fewer (11%) had net-zero goals (UNWTO, 2023, no page).

This paper focuses on the situation of large tourism firms. For many of these, emission data is available for Scopes 1,2 and 3 based on the accounting and reporting standard for firms introduced in 2001 by the Greenhouse Gas Protocol (2022). Scopes refer to direct emissions that

are owned or controlled by a company (scope 1), indirect emissions from the generation of purchased electricity, steam, heat, or cooling (scope 2), and upstream/downstream emissions caused by activities of a company, but not sourced or controlled by it (scope 3), including emissions from suppliers. Companies need to take responsibility for scope 1–2 emissions, as scope 3 emissions are technically the scope 1–2 of other companies. Yet, scope 3 emission assessments are important, as they indicate the amount of carbon that is caused by specific tourism activities, and thus advice on systemic effects of specific consumption patterns.

3. Method

To decide which companies to include in the sample, we initially consulted Bloomberg, a provider of business and financial information that lists the largest companies in air transport, the cruise sector and hotel chains, by market capitalization (stock market value). For the three subsectors, Bloomberg provides data for 26 airlines, 3 cruise lines, and 27 hotel chains. These constitute the original sample of companies studied in this paper. To ensure that the data is accurate, these companies’ annual reports were identified and downloaded. A comparison with Bloomberg data for airlines and cruise lines did not indicate any inconsistencies between Bloomberg data and annual reports. Accommodation data was thus trusted as provided by Bloomberg. As emission and economic data is not available for all listed tourism companies, and for the study period 2015–2019, this reduced the sample to 16 airlines, 2 cruise lines, and 11 hotel chains. For these, data was compiled for the period 2015–2019 as well as the years 2020–2022, to understand the effects of the COVID-pandemic. More specifically, available data for the 29 companies includes emissions (total, scope 1–2), revenue (total, in US \$), revenue passenger kilometres (RPK) (airlines), passenger numbers (cruises), and room estimates (accommodation). Integrated environmental-economic indicators are developed from this data, including emissions in kg CO₂ per US\$ of revenue (all subsectors) as well as kg CO₂ per RPK (airlines), kg CO₂ per passenger (cruises) and kg CO₂ per room (hotel chains). Indicators were calculated by dividing revenue in million US\$ by total CO₂ emissions in thousand metric tons (as well as per million revenue passenger kilometres, million passengers, or million room nights).

Scope 3 emissions are not considered in these calculations. There are 15 types of scope 3 emissions, such as purchased goods and services, waste, or employee commuting. While a tourism business is not technically accountable for these emissions, scope 3 is relevant when considering the total climate impact of a tourist trip or vacation. In the discussion of individual contributions to climate change, such as a 7-day all-inclusive cruise package relying on many supply-chain inputs, it is meaningful to consider scopes 1–3.

All large tourism firms have a pro-growth agenda that makes total emission reductions more difficult (Gössling et al., 2022). To assess future growth implications for decarbonization, revenue and emissions are extrapolated for each of the three subsectors to 2050, based on industry expectations for market growth and emissions efficiency improvement. Data are obtained from reports with differing degrees of reliability: commercial air transport data are provided by the International Energy Agency (IEA, 2023a, pp. 1900–2022); cruise line data by Cruise Market Watch (2023); and accommodation data by STA (2017) and Statista Market Insights (2023). Industry data need to be treated with caution and should be considered indicative.

We assume that all three sectors will return to 2019 levels in 2024 (in traveller numbers) and that they continue to grow in line with business projections (aviation) or following observed trends in 2015–2019 (cruise and hotel). We consider that emission efficiencies will improve over time. Two emissions efficiency ratios (emissions per RPK, per passenger and per room) in 2050 are computed. One is based on a business-as-usual scenario and projected to 2050 using the sectoral average improvement rate for 2015–2019. The second is calculated

against the goal to reduce sectoral emissions by 90%, 95% and 99% in 2050, compared to 2019. This illustrates the necessary technology improvement rate for net-zero under continued growth. It should also be noted that all economic data are presented in nominal US\$, as annual report data are not inflation-adjusted. The figures cover CO₂ for air transport and cruises, and CO₂e for accommodation (this includes emissions of carbon dioxide, methane and nitrous oxide). Non-CO₂ warming from aviation (Lee et al., 2021) is not considered, essentially implying that contributions to climate change are underestimated.

For air transport, the assumption is that the sector will continue to grow at a rate of 2.4%–3.9% per year (in RPK; Airbus, 2022; Boeing, 2022; Dray et al., 2022). These growth rates need to be weighed against efficiency gains to derive overall growth in emissions. Data for 16 airlines for the period 2015–2019 suggests an efficiency improvement rate of 2.1% per year. This rate is used to calculate future emission intensities (in kg CO₂ per RPK), which is then multiplied with the projected RPK numbers to derive total emissions in 2050. Revenue growth is assumed to equal RPK growth (adjusted $r^2 = 0.94$) for future years.

The cruise sector anticipates passenger numbers to grow in the order of 6.6% per year, with efficiency gains of 2% per year (kg CO₂ per passenger) (Cruise Market Watch, 2023; WRI 2023). Revenue is expected to grow by 7.3% per year, the average value for the two largest cruise lines (Carnival and Royal Caribbean) observed in the period 2015–2019. Using these parameters, we project emissions growth, emissions efficiency and revenue over the 26 years to 2050.

Accommodation growth is calculated based on the Sustainable Tourism Alliance (STA, 2017) and Statista (2022), with growth rates of in between 1.6% (Statista) and 2.9% (STA) per year (hotel room numbers) over the period 2010–2018. Sectoral revenue and room data are obtained from Statista, while the emission intensity for rooms (6.8t CO₂/year/room in 2019) is from STA (2017). STA (ibid.) also uses two decarbonization rates to assess future decarbonization trends: 3.3% (2010–2014) and 1.4% (2010–2050), which we use for projections to 2050. As with other industry data, past decarbonization trends cannot be verified, nor it is clear whether future decarbonization rate assumptions are robust.

The analysis follows a general decomposition analysis approach, in which emissions and revenue developments are compared over time. Comparison requires specification of system boundaries to provide valid, consistent and comparable calculations (Sun et al. 2019, 2020). By comparing scope 1–2 emissions and revenue, this comparability of data is ensured, as the approach will cover, if extended globally, all emissions and all revenue.

4. Results

Table 1 provides an overview of the three subsectors and the share of global tourism these represent. Together, the 29 firms emitted 365 Mt CO₂ in 2019, and generated US\$477 billion in revenue. Scope 1–2 data suggests that the 16 airlines accounted for one third (32%) of global emissions from commercial air transport in 2019. This share was significantly higher for the two cruise lines (68%) and lower for the sample of hotels (12%). In terms of revenue, the airlines investigated stand for 44%, the cruise lines for 63%, and the hotels for 20% of the total revenue generated by these subsectors. This suggests that the sample includes airlines and hotel chains that have a significantly higher share in revenues than in emissions, with favourable carbon-intensities (low levels of emissions per US\$), while the two cruise lines contribute a larger share of emissions than they receive in revenue. Other cruise lines thus have higher revenues in comparison to emissions. The data also suggests that the airlines studied are more efficient than the global average, as they provide 37% of RPK globally, in comparison to 32% of emissions. To a lesser degree, this is also true for the cruise lines, which carry 70% of passengers, and generate 68% of emissions. Accommodation accounts for 21% of revenue, in comparison to 12% of emissions, suggesting low emissions per unit of value in comparison to the global

Table 1

Share of emissions represented by sample in 2019 (scope 1–2).

Subsector	Emissions Mt CO ₂	Revenue Billion US\$	RPK (trillion)	Pax (million)	Rooms (million)
Aviation (total)	1036	838	8.7		
Airline sample (n = 16)	332	366	3.2		
Sample % of total	32%	44%	37%		
Cruises (total)	23	51		28	
Cruise sample (n = 2)	16	32		19	
Sample % of total	68%	63%		70%	
Accommodation (total)	141	369			17
Accommodation (n = 20) ^a	17	79			3.4
Sample % of total	12%	21%			20%

^a Number based on different years, without rooms for Genting Malaysia, as no data available.

Source: Annual reports (see list of references); Humpe et al. (2023); ICAO (2023); IEA (2023a); STA, 2017; UNFCCC (2018).

average.

4.1. Airlines

Scope 1–2 data was identified for 16 of the 26 airlines listed by Bloomberg for 2019 (Table 2). American Airlines and Delta are the largest emitters, with emissions of 41.4 and 37.6 Mt CO₂, respectively. There are several other airlines producing in the order of 30 Mt CO₂ per year, such as Air France-KLM, China Southern Airlines, Deutsche Lufthansa, International Consolidated Airlines Group, and United Airlines. Annual emission growth rates in the period 2015–2019 have ranged between 0.6% (Korean Air Lines) and 13.3% (Alaska Air Group Inc). American Airlines is the only airline that reduced absolute emissions in this period, by –0.4% per year.

Table 2 also provides longitudinal data. The analysis shows that scope 1–2 emissions grew from 305 Mt CO₂ in 2015 to 332 Mt CO₂ in 2019 for the 16 airlines providing continuous data for the entire period, or at 2.1% per year. Even though this growth rate varies, from –0.4% per year for American Airlines to 13.3% per year for Alaska Air group, the average rate for the sample is lower rate than for the entire sector, at 4.3% (Gössling & Humpe, 2020). This is likely to reflect on the size of airlines and the maturity of their markets. Further insights are revealed by economic data. The combined revenue of the 16 airlines reporting for the period 2015–2019 grew from US\$324 billion to US\$366 billion in this period, representing an average 3.1% growth in CAGR (economic data not inflation-adjusted; Table 3).

Table 4 provides an overview over developments for key indicators for the 16 airlines providing data for this period (see also Table 2). The data suggests that for these airlines, the carbon intensity in kg per US\$ of revenue declined by 1% per year, from 0.94 to 0.91 kg/US\$. The carbon intensity in kg per RPK declined by 2.1% per year, from 0.11 to 0.10 kg/RPK. Yet, the data also reveals that there is no linear trend for relations of emissions with revenue, as the ratio was “best” in 2016 and “worst” in 2018.

Against this background, an important question is how emissions from air transport will develop in the future, and which efficiency improvement rates would be required to stay on track to net-zero. Under the assumption that RPK growth will continue with 2.4%–3.9% per year to 2050, the range of industry projections and an estimate by Dray et al. (2022) suggests that the sector will grow to between 16.1 and 23.5 trillion RPK by 2050 (Table 5). The scenario is also based on the assumption that air transport demand will return to 2019 levels in 2024. As Table 5 illustrates, emission intensities will decline in all three scenarios to 0.07 kg CO₂ per RPK, or 0.72 kg CO₂ per US\$ of revenue,

Table 2Scope 1–2 emissions for airlines, Mt CO₂.

Airline	2015	2016	2017	2018	2019	2020	2021	2022	CAGR ^a
Air Canada	10.24	11.11	12.23	12.89	13.22	5.04	4.92		6.59%
Air China Ltd						15.04	15.44	10.05	
Air France-KLM	27.65	27.41	27.62	27.69	28.30	14.05	16.36	22.64	0.58%
Alaska Air Group Inc	4.84	5.10	7.50	7.76	7.99	4.18	5.97		13.34%
American Airlines Group Inc	42.04	39.25	39.39	40.60	41.42	20.08	29.06		−0.37%
ANA Holdings Inc	10.73	11.26	11.61	11.56	12.46	5.48	7.77		3.79%
Cathay Pacific Airways Ltd	17.45	17.28	18.08	18.48	18.50	7.59	6.06	5.39	1.46%
China Eastern Airlines Corp Ltd				21.00	22.75	13.95	15.87	9.94	
China Southern Airlines Co Ltd					28.53	19.46	19.24	14.50	
Delta Air Lines Inc	35.35	35.72	36.41	37.27	37.62	17.45	24.81	30.94	1.57%
Deutsche Lufthansa AG	28.94	29.53	29.21	32.98	33.55	11.64	13.96	23.34	3.76%
easyJet PLC					8.33	4.25	2.12	6.42	
Eva Airways Corp	5.51	5.93	6.32	6.27	6.13	4.32	4.14	4.50	2.72%
Hainan Airlines Holding Co Ltd									
InterGlobe Aviation Ltd							2.94	3.12	
International Con. Airlines	26.52	28.36	28.85	30.08	30.76	11.03	10.93	21.16	3.78%
Japan Airlines Co Ltd	8.62	8.82	9.14	9.40	9.18	4.47	6.27		1.59%
Juneyao Airlines Co Ltd									
Korean Air Lines Co Ltd	13.10	13.39	13.42	13.36	13.40	7.68	7.55	8.67	0.57%
Latam Airlines Group SA	11.63	11.36	11.08	11.53	12.17	5.63	6.51	9.79	1.14%
Qantas Airways Ltd	11.86	12.21	12.39	12.53	12.49	9.42	3.30	4.80	1.30%
Ryanair Holdings PLC			9.90	11.00	11.80	12.70	2.90	9.20	
Singapore Airlines Ltd		13.94	14.08	14.17	16.50	16.31	3.97	7.81	
Southwest Airlines Co	18.78	19.72	20.20	20.58	20.19	12.40	16.21	18.66	1.82%
Spring Airlines Co Ltd									
United Airlines Holdings Inc	31.73	31.73	32.76	33.47	34.60	15.67	21.53	30.54	2.19%
Sum (n = 16)	305.00	308.19	316.18	326.45	331.97	156.15	185.34	180.43	2.14%

^a CAGR: Compound annual growth rate, 2015–2019.

Source: Annual reports, see list of references and Bloomberg

Table 3

Airline revenue (USD millions).

Airline	2015	2016	2017	2018	2019	2020	2021	2022	CAGR ^a
Air Canada	10,859	11,086	12,529	13,895	14,419	4354	5106	12,729	
Air China Ltd	16,610	16,158	17,979	20,693	19,718	10,084	11,556	7866	
Air France-KLM	28,517	27,500	29,223	30,977	30,438	12,660	16,931	27,799	
Alaska Air Group Inc	5598	5931	7894	8264	8781	3566	6176	9646	
American Airlines Group Inc	40,990	40,180	42,622	44,541	45,768	17,337	29,882	48,971	
ANA Holdings Inc	15,665	14,932	16,329	17,797	18,566	18,160	6874	9087	
Cathay Pacific Airways Ltd	13,201	11,949	12,484	14,170	13,653	6051	5865	6518	
China Eastern Airlines Corp Ltd	14,955	14,894	15,181	17,441	17,517	8520	10,408	6857	
China Southern Airlines Co Ltd	17,769	17,315	18,934	21,729	22,344	13,429	15,760	12,946	
Delta Air Lines Inc	40,704	39,450	41,138	44,438	47,007	17,095	29,899	50,582	
Deutsche Lufthansa AG	35,582	35,042	40,194	41,980	40,776	15,515	19,883	34,516	
easyJet PLC	7240	6649	6396	7936	8150	3837	1996	7384	
Eva Airways Corp	4321	4490	5377	5971	5868	3025	3719	4634	
Hainan Airlines Holding Co Ltd	5589	6126	8875	10,252	10,481	4266	5272	3400	
InterGlobe Aviation Ltd	2269	2453	2751	3490	4029	4990	1914	3443	
International Con. Airlines	25,372	24,978	25,848	28,652	28,554	8912	10,000	24,295	
Japan Airlines Co Ltd	12,294	11,143	11,924	12,485	13,415	12,749	4539	6080	
Juneyao Airlines Co Ltd	1296	1495	1839	2173	2425	1466	1825	1221	
Korean Air Lines Co Ltd	10,207	10,117	10,700	11,830	10,631	6462	7879	10,941	
Latam Airlines Group SA	9740	8988	9614	9895	10,070	3924	4884	9363	
Qantas Airways Ltd	13,232	11,802	12,108	13,278	12,849	9573	4434	6609	
Ryanair Holdings PLC	7173	7218	7295	8371	8913	9440	1909	5581	
Singapore Airlines Ltd	12,092	11,000	10,748	11,658	12,021	11,650	2795	5646	
Southwest Airlines Co	19,820	20,425	21,146	21,965	22,428	9048	15,790	23,814	
Spring Airlines Co Ltd	1284	1269	1625	1984	2143	1360	1684	1245	
United Airlines Holdings Inc	37,864	36,556	37,784	41,303	43,259	15,355	24,634	44,955	
Sum for sample (n = 16)	323,966	314,571	336,913	361,442	366,482	163,785	196,496	330,538	3.13%

^a CAGR: Compound annual growth rate, 2015–2019.

Source: Annual reports, see list of references and Bloomberg

should emission intensities (in kg CO₂ per RPK) continue to improve by 2.1% per year.

If revenue continues to grow at the same speed as RPK numbers (adjusted $r^2 = 0.94$), the sector's future emissions trajectory can be assessed on this basis. This again allows to calculate the efficiency improvement rates necessary to stay on track to net-zero in 2050. Table 6 shows how emissions will develop for aviation in a business-as-

usual (BAU) scenario, and which efficiency gains will be required to achieve 90%, 95% and 99% reductions in absolute emissions in 2050. In the BAU scenario, and under consideration of efficiency gains of 2% per year, emissions will continue to grow to between 1.1 and 1.6 Gt CO₂ in 2050. In this scenario, accumulated emissions between 2024 and 2050 will exceed 30 Gt CO₂, and deplete a significant share of the remaining carbon budget (Gössling et al., 2022). To reduce emissions by 99% by

Table 4

Emissions, revenue, and emission intensities for 16 airlines, scope 1-2.

Sample (n = 16 airlines)	2015	2016	2017	2018	2019	Annual growth rate
Mt of CO ₂	305.00	308.19	316.18	326.45	331.97	2.1%
Revenue (million US\$)	323,966	314,570	336,913	361,442	366,482	3.1%
Revenue Passenger Kilometres (trillion)	2.67	2.77	2.92	3.07	3.18	4.4%
Carbon intensity (kg/US\$ revenue)	0.94	0.98	0.94	0.90	0.91	−1.0%
Carbon intensity (kg/RPK)	0.11	0.11	0.11	0.11	0.10	−2.1%

Source: based on annual reports, see list of references

Table 5

Emissions and revenue projection for the global aviation sector.

Aviation	2019	2030	2050	2030	2050	2030	2050
Growth rate of RPK per annum	Baseline	2.40% (Dray et al., 2022)	3.80% (Boeing)			3.90% (Airbus)	
Emissions (Mt) (Scope 1 + 2)	1,036 ¹	1054	1115	1143	1587	1150	1627
Revenue (billion USD)	838 ²	966	1553	1048	2210	1054	2266
Revenue Passenger Kilometres (trillion)	8.7 ³	10.0	16.1	10.9	22.9	10.9	23.5
Emission intensity (kg/\$US revenue)	1.24	1.09	0.72	1.09	0.72	1.09	0.72
Emissions intensity (kg/RPK)	0.12	0.11	0.07	0.11	0.07	0.11	0.07

Source: ICAO (2023); IATA (2019); IEA (2022).

Table 6

Efficiency improvement required for net-zero, air transport.

RPK growth scenarios	2.4% (Dray et al., 2022)	3.8% (Boeing)	3.9% (Airbus)
Scenario 1: Business as usual (BAU) to 2050			
Emissions (Mt) (Scope 1–2)	1115	1587	1627
Revenue Passenger Kilometres (Trillions)	16.10	22.91	23.49
Emissions intensity (kg/RPK)	0.07	0.07	0.07
Scenario 2: 90% emissions reduction by 2050			
Emissions (Mt) (Scope 1–2)	104	104	104
Emissions intensity (kg/RPK)	0.006	0.005	0.004
Necessary annual efficiency improvement rate	11%	12%	12%
Scenario 3: 95% emissions reduction by 2050			
Emissions (Mt) (Scope 1–2)	52	52	52
Emissions intensity (kg/RPK)	0.003	0.002	0.002
Necessary annual efficiency improvement rate	13%	14%	14%
Scenario 4: 99% emissions reduction by 2050			
Emissions (Mt) (Scope 1–2)	10	10	10
Emissions intensity (kg/RPK)	0.001	0.0005	0.0004
Necessary annual efficiency improvement rate	18%	19%	19%

2050, the scenario most closely aligned with a net-zero trajectory, will require emission intensities to improve by 18%–19% per year. Even the less ambitious 90% emission reduction scenario would presuppose an annual efficiency improvement rate of 11%–12% per year. This illustrates the difficulty of aligning an expanding air transport system with climate change mitigation goals. Without demand management reducing growth rates, it is highly unlikely that aviation can stay on track to become a net-zero sector. As discussed earlier, these calculations do not consider non-CO₂ warming that is likely to persist - at least partially - even under full fuel-transition scenarios (Dray et al., 2022) (see Table 7).

4.2. Cruise lines

Cruise line emissions for Carnival and Royal Caribbean increased from 14.8 Mt CO₂ in 2015 to 15.6 Mt CO₂ in 2019 (scope 1–2). This is equivalent to a growth rate of between 0.93% per year (Carnival) and 2.06% per year (Royal Caribbean). As revenue grew at 7.18%–7.29% per year (Carnival and Royal Caribbean), emission intensities improved by 5.93%–4.78% per year, to 0.52 kg CO₂ per US\$ of revenue (Carnival) and 0.44 kg CO₂ per US\$ (Royal Caribbean) in 2019. The data also reveals that sailing restrictions and lower load factors during the COVID-pandemic increased these values to 2.34 kg CO₂ per US\$ of revenue (Carnival) and 1.69 kg CO₂ per US\$ of revenue (Royal Caribbean) in 2021.

While the two cruise lines achieved very significant improvements in emission intensities over the period 2015–2019, data reveals that this has not led to a decline in absolute emissions. Furthermore, values refer to scope 1–2 emissions. Including scope 3 emissions doubles emission values. While scope 3 emissions are not technically the responsibility of the cruise line, these support the supply chain. This means that while per-passenger emissions for an average cruise with a length of 7.2 days have declined from 913 kg CO₂ in 2015 to 804 kg CO₂ in 2019, the amount of emissions caused by the cruise is rather in the order of 1.6 t CO₂ (Humphe et al., 2023). This latter value represents the carbon footprint associated with a cruise trip if including scope 3 emissions. As many cruises also involve air travel to the port of departure, from the port of arrival, or both, the average cruise is likely even more carbon intense: at an emission intensity of 0.12 kg CO₂ per RPK, air travel adds about 120 kg CO₂ per 1000 km of distance. This can again double the amount of CO₂ involved in a cruise. Data confirms that cruises are the most carbon-intensive forms of tourism catering to a mass market, specifically in combination with a flight. Adding long-haul air transport, a cruise trip can cause emissions within one week that are equivalent to the annual emissions of a person on global average (4.7 t CO₂ in 2021; IEA, 2023b).

An extrapolation of the data that is available for Carnival and Royal Caribbean leads to the conclusion that the sector's emissions of 23 Mt CO₂ (scope 1–2) and revenues of US\$50.5 billion in 2019 will grow to 70.9 Mt CO₂ and US\$311.6 billion in 2050 (Table 8). While the emission intensity per US\$ of revenue is anticipated to fall from 0.45 kg CO₂ per US\$ in 2019 to 0.23 kg CO₂ per US\$ in 2050, and per passenger emissions from 827.3 kg CO₂ per trip in 2019 to 489.3 kg CO₂ per trip in 2050 (at the same trip length of 7.2 days), the expected five-fold growth in passenger numbers to 145 million in 2050 outpaces efficiency gains. Growth can consequently not be aligned with net-zero goals. This is shown in Table 9, which illustrates that a reduction in emissions by 90% would require an annual efficiency improvement rate of 12%. To decarbonize by 99% requires a 20% efficiency improvement rate per year. This is not realistically achievable.

4.3. Hotels

Data on global accommodation establishment numbers are not available. Sustainable Tourism International (STA, 2017) estimates that there have been 21 million hotel rooms and hotel-related emissions of 140.7 Mt CO₂ in 2019 (extrapolation of data for the period 2010–2014).

Table 7

Emissions, revenue, passengers and intensity for cruise lines.

	2015	2016	2017	2018	2019	2020	2021	2022	CAGR ^a
Cruise Line emissions scope 1–2 (millions of metric tons)									
Carnival Cruises	10.38	10.54	10.69	10.70	10.77	6.30	4.47	8.63	0.93%
Royal Caribbean	4.46	4.48	4.23	4.38	4.84	2.50	2.59	4.99	2.06%
Total	14.83	15.01	14.92	15.08	15.60	8.80	7.06	13.62	1.27%
Revenues (million USD)									
Carnival Cruises	15,714	16,389	17,510	18,881	20,825	5595	1908	12,168	7.29%
Royal Caribbean	8299	8496	8778	9494	10,951	2209	1532	8841	7.18%
Total	24,013	24,885	26,288	28,375	31,776	7804	3440	21,009	7.25%
Passengers (million)									
Carnival Cruises	10.84	11.52	12.13	12.41	12.87	3.50	1.22	7.70	4.38%
Royal Caribbean	5.40	5.75	5.77	6.08	6.55	1.30	5.54		4.95%
Total	16.24	17.27	17.89	18.49	19.42	4.79	6.76	7.70	4.57%
Emission intensity (kg/\$US revenue)									
Carnival Cruises	0.66	0.64	0.61	0.57	0.52	1.13	2.34	0.71	–5.93%
Royal Caribbean	0.54	0.53	0.48	0.46	0.44	1.13	1.69	0.56	–4.78%
Average	0.62	0.60	0.57	0.53	0.49	1.13	2.05	0.65	–5.58%
Emission intensity (kg/passenger)									
Carnival Cruises	957	915	881	862	837	1800	3655	1120	–3.30%
Royal Caribbean	825	778	734	720	738	1932	468		–2.76%
Average	913	869	834	815	804	1836	1045	1768	–3.15%

^a Average for the period 2015–2019.

Source: Annual reports, see list of references and Bloomberg

Table 8

Emissions and revenue projection for the cruise sector, 2019–2050.

Cruises	2019	2025	2030	2040	2050	CAGR
Emissions (Mt CO ₂) (Scope 1–2)	22.8	23.8	29.6	45.8	70.9	4.5%
Revenue (billion US\$)	50.5	54.2	76.9	154.8	311.6	7.3%
Passenger numbers (million)	27.5	29.3	40.4	76.5	144.9	6.6%
Emission intensity (kg/US\$ revenue)	0.45	0.44	0.38	0.30	0.23	–2.6%
Emissions intensity (kg/pax)	827.3	810.8	732.9	598.8	489.3	–2.0%

Source: Humpe et al. (2023-a); Cruise Market Watch (2023).

Table 9

Efficiency improvement required for net-zero, cruises.

	2050
Scenario 1: BAU to 2050	
Emissions (Mt) (Scope 1 + 2)	70.9
Passenger number (million)	144.9
Emission intensity (kg/pax)	489.3
Scenario 2: 90% emissions reduction by 2050	
Emissions (Mt) (Scope 1 + 2)	2.3
Emission intensity (kg/pax)	15.7
Annual efficiency improvement rate	12%
Scenario 3: 95% emissions reduction by 2050	
Emissions (Mt) (Scope 1 + 2)	1.1
Emission intensity (kg/pax)	7.9
Annual efficiency improvement rate	15%
Scenario 4: 99% emissions reduction by 2050	
Emissions (Mt) (Scope 1 + 2)	0.2
Emission intensity (kg/pax)	1.6
Annual efficiency improvement rate	20%

Similar values (17 million rooms in 2019) have been published by [Statista \(2022\)](#). [STA \(2017\)](#) data suggests a CAGR of 2.9%; a lower rate of 1.6% has been presented by [Statista \(2022\)](#). As emissions per hotel room fell from 9.23 to 6.8 t CO₂ per year (–3.34% per year), efficiency gains in the accommodation sector surpassed the growth rate ([STA, 2017](#)), suggesting that emissions declined from absolute levels at an annual rate of –0.53% per year.

[Table 10](#) shows that the situation is different for n = 11 large hotel chains providing data for 2015–2019. These chains increased their

emissions from 12.1 Mt CO₂ in 2015 to 17.3 Mt CO₂e in 2019, i.e. at a CAGR of 9.33%. Data shows that CAGRs vary significantly between firms, from –27.2% per year (Whitbread PLC) to 21.4% per year (MGM China Holdings). However, changes in Whitbread's emissions between 2016 and 2017 are partly due to changes in reporting, and figures are therefore neither comparable nor reliably indicative of emission reductions. The significant changes observable between individual years nevertheless suggest that acquisitions or sales have considerable influence on emission developments in absolute terms. [Table 10](#) also indicates that the overall reporting situation has improved, as a growing number of hotels are providing data on emissions, though the reporting is still not as consistent as it is for revenue ([Table 11](#)).

[Table 12](#) shows that emission intensities (kg CO₂e per US\$) increased from 0.20 kg CO₂e per US\$ in 2015 to 0.22 kg CO₂e per US\$ in 2019, representing a CAGR of 2.28%. This value needs to be treated with caution, however, as emission intensities fluctuated during this period. There is also considerable variation between hotel chains, with emissions per US\$ varying by a factor 100 in 2019, from 0.01 kg CO₂e per US\$ (SIM Holdings) to 1.04 kg CO₂e per US\$ (Fosun International). Firm-specific CAGRs for the period 2015–2019 range between –18.5% (Whitbread PLC) and 13.5% (MGM China Holdings). The significant differences in values and CAGRs underline the difficulty of comparing firms, as well as to determine specific trends. COVID-years also confirm that occupancy rates have considerable relevance for emissions, as these increased to 0.40 kg CO₂e per US\$ in 2020. For some chains, emissions appear to have grown significantly during the pandemic, by up to a factor 30. For instance, SJM report values of 0.01 kg CO₂e per US\$ during the period 2015–2019, but these went up to 0.3 kg CO₂e in 2021. Further research is needed to explain these sudden changes as well as the variation observed between hotel chains, which may be explained with acquisitions, sales, hotel types (city, resort, casino), or franchisees. The latter have importance, in that franchisees pay commissions (increasing revenues for chains), while emissions from franchises do not fall under scopes 1–2 for the chains to which these franchises belong.

[Table 13](#) illustrates developments and variation in emissions per room and year. This data is inconsistent and thus not used for extrapolation. Again, the data reveals large differences in the emissions reported, from 0.2 t CO₂e per room per year (Wyndham; though this may be a result of changes in reporting), to 93.3 t CO₂e per room per year (Wynn Macau) in 2019. Median data for 2019, at 6.26 tons of CO₂e per room and year, is close to the extrapolated average value of 6.8 t CO₂e per room and year presented by [STA \(2017\)](#). While the data also suggests

Table 10Scope 1–2 emissions for hotels, thousands of metric tons CO₂e.

Thousand ton CO ₂ e	2015	2016	2017	2018	2019	2020	2021	2022	CAGR 2015–2019
MARRIOTT INTERNATIONAL -CL A	3915	6834	6418	6836	6809	5166	5831		14.84%
LAS VEGAS SANDS CORP	1014	1035	1002	860	855	523	586	431	−4.18%
HILTON WORLDWIDE HOLDINGS		2359	2291	2378	2408	1718	2177	2351	
GALAXY ENTERTAINMENT GROUP				876	1942	1666	1185	560	
SANDS CHINA LTD		772	807	748	744	440	509	332	
MGM RESORTS INTERNATIONAL	915	759	866	816	968	709	730	652	1.43%
H WORLD GROUP LTD						257	295	287	
INTERCONTINENTAL HOTELS GROUP	2335	2341	2340	2428	2674	1925	2222	2483	3.44%
WYNN RESORTS LTD					298	225	409		
ACCOR SA	1727	1859	1957	2110	3471	2273	2783	2928	19.07%
WHITBREAD PLC	275	266	94	77	77	51	70	71	−27.20%
BOYD GAMING CORP							269		
INDIAN HOTELS CO LTD		211	190	205	292	290	145		
CHOICE HOTELS INTL INC								16	
WYNDHAM HOTELS & RESORTS INC				293	170	139	163	151	
SHANGHAI JINJIANG INTERNAT-A									
FOSUN INTERNATIONAL LTD					21,510	22,130	21,970	20,690	
HYATT HOTELS CORP - CL A	1575	1574	1575	1558	1836	1286	1563		3.91%
MINOR INTERNATIONAL PCL			216	313	334	290	343	501	
HILTON GRAND VACATIONS INC									
WYNN MACAU LTD	135	183	273	250	253	188	204	148	17.00%
MGM CHINA HOLDINGS LTD	74	71	70	159	162	140	158	112	21.42%
BTG HOTELS GROUP CO LTD-A									
GENTING MALAYSIA BHD	105	91	282	256	178	178	173	237	14.30%
SJM HOLDINGS LTD	69	66	63	60	60	110	391	181	−3.60%
NAGACORP LTD		4	4	39	39	15	12	23	
SH JINJIANG INTL HOTELS - B									
Sum for firms reporting 2015–2019 (n = 11)	12,140	15,078	14,941	15,410	17,344	12,549	14,712		9.33%

Source: Annual reports, see list of references and Bloomberg

Table 11

Revenue for hotels.

Revenues (million USD)	2015	2016	2017	2018	2019	2020	2021	2022	CAGR 2015–2019
MARRIOTT INTERNATIONAL -CL A	14,486	17,072	20,452	20,758	20,972	10,571	13,857	20,773	9.69%
LAS VEGAS SANDS CORP	11,688	11,410	12,728	13,729	13,739	2940	4234	4110	4.12%
HILTON WORLDWIDE HOLDINGS IN	7133	6576	8131	8906	9452	4307	5788	8773	7.29%
GALAXY ENTERTAINMENT GROUP L	6577	6805	6242	7044	6624	1660	2534	1465	0.18%
SANDS CHINA LTD	6820	6653	7586	8665	8808	1687	2874	1605	6.60%
MGM RESORTS INTERNATIONAL	9190	9478	10,797	11,763	12,900	5162	9680	13,127	8.85%
H WORLD GROUP LTD	919	985	1219	1522	1623	1479	1982	2061	15.29%
INTERCONTINENTAL HOTELS	1803	3912	4075	4337	4627	2394	2907	3892	26.57%
WYNN RESORTS LTD	4076	4466	6070	6718	6611	2096	3764	3757	12.85%
ACCOR SA	1518	1822	3134	3876	4533	1851	2607	4449	31.44%
WHITBREAD PLC	4245	4420	4109	2636	2704	2648	763	2337	−10.66%
BOYD GAMING CORP	2199	2184	2401	2627	3326	2178	3370	3555	10.89%
INDIAN HOTELS CO LTD	685	615	600	637	646	630	212	410	−1.48%
CHOICE HOTELS INTL INC	860	925	941	1041	1115	774	1069	1402	6.71%
WYNDHAM HOTELS & RESORTS INC	1301	1269	1280	1868	2053	1300	1565	1498	12.08%
SHANGHAI JINJIANG INTERN.	861	1602	2012	2224	2186	1436	1768	1637	26.22%
FOSUN INTERNATIONAL LTD	12,540	11,138	13,041	16,544	20,702	19,839	25,009	26,082	13.35%
HYATT HOTELS CORP - CL A	4328	4265	4462	4454	5020	2066	3028	5891	3.78%
MINOR INTERNATIONAL PCL	1238	1450	1622	2320	3835	1790	2175	3428	32.66%
HILTON GRAND VACATIONS	1475	1583	1711	1999	1838	894	2335	3835	5.65%
WYNN MACAU LTD	2463	2847	4367	5052	4615	981	1509	721	17.00%
MGM CHINA HOLDINGS LTD	2215	1920	1858	2450	2906	657	1211	673	7.02%
BTG HOTELS GROUP CO LTD-A	201	982	1247	1292	1203	766	954	757	56.46%
GENTING MALAYSIA BHD	2144	2157	2170	2459	2490	1063	986	1927	3.81%
SJM HOLDINGS LTD	6303	5385	4077	4390	4323	968	1296	853	−8.99%
NAGACORP LTD	504	532	956	1474	1755	879	214	436	36.64%
SH JINJIANG INTL HOTELS - B	861	1602	2012	2224	2186	1436	1768	1637	26.22%
Sum for n = 11 ^a	60,383	64,688	72,230	75,904	78,829	31,301	42,077	58,752	6.89%

^a For n = 11 hotels also reporting consistent emissions data for 2015–2019 (Table 11).

Source: Annual reports, see list of references and Bloomberg

that emissions per room have declined significantly between 2015 and 2019, there is evidence of the significant impact of the COVID pandemic on emissions. Notably, emissions were apparently lower in 2020, possibly because hotels shut down, and higher in 2021, as a likely result of the restart with low occupancy rates.

Table 14 illustrates developments in emissions and revenues for the

accommodation sector, using two CAGRs, i.e. 1.6% (Statista, 2022) and 2.9% (STA, 2017). Base year revenue and room number data is derived from Statista (2022), with emission intensities per room being based on STA (2017). STA (2017) suggests a decarbonization rate of 1.4% for the period 2010–2050. The extrapolation suggests that accommodation sector emissions are likely to fall to mid-century, though far from the

Table 12Emission intensities accommodation, kg CO₂e per US\$.

kg/\$US	2015	2016	2017	2018	2019	2020	2021	2022	CAGR 2015–2019
MARRIOTT INTERNATIONAL -CL A	0.27	0.40	0.31	0.33	0.32	0.49	0.42		4.69%
LAS VEGAS SANDS CORP	0.09	0.09	0.08	0.06	0.06	0.18	0.14	0.10	−7.97%
HILTON WORLDWIDE HOLDINGS IN		0.36	0.28	0.27	0.25	0.40	0.38	0.27	
GALAXY ENTERTAINMENT GROUP L				0.12	0.29	1.00	0.47	0.38	
SANDS CHINA LTD		0.12	0.11	0.09	0.08	0.26	0.18	0.21	
MGM RESORTS INTERNATIONAL	0.10	0.08	0.08	0.07	0.08	0.14	0.08	0.05	−6.82%
H WORLD GROUP LTD						0.17	0.15	0.14	
INTERCONTINENTAL HOTELS GROUP	1.30	0.60	0.57	0.56	0.58	0.80	0.76	0.64	−18.27%
WYNN RESORTS LTD					0.05	0.11	0.11		
ACCOR SA	1.14	1.02	0.62	0.54	0.77	1.23	1.07	0.66	−9.42%
WHITBREAD PLC	0.06	0.06	0.02	0.03	0.03	0.02	0.09	0.03	−18.52%
BOYD GAMING CORP							0.08		
INDIAN HOTELS CO LTD		0.34	0.32	0.32	0.45	0.46	0.68		
CHOICE HOTELS INTL INC								0.01	
WYNDHAM HOTELS & RESORTS INC				0.16	0.08	0.11	0.10	0.10	
SHANGHAI JINJIANG INTERNAT-A									
FOSUN INTERNATIONAL LTD					1.04	1.12	0.88	0.79	
HYATT HOTELS CORP - CL A	0.36	0.37	0.35	0.35	0.37	0.62	0.52		0.13%
MINOR INTERNATIONAL PCL			0.13	0.14	0.09	0.16	0.16	0.15	
HILTON GRAND VACATIONS INC									
WYNN MACAU LTD	0.05	0.06	0.06	0.05	0.05	0.19	0.14	0.21	0.00%
MGM CHINA HOLDINGS LTD	0.03	0.04	0.04	0.06	0.06	0.21	0.13	0.17	13.46%
BTG HOTELS GROUP CO LTD-A									
GENTING MALAYSIA BHD	0.05	0.04	0.13	0.10	0.07	0.17	0.18	0.12	10.10%
SJM HOLDINGS LTD	0.01	0.01	0.02	0.01	0.01	0.11	0.30	0.21	5.92%
NAGACORP LTD		0.01	0.00	0.03	0.02	0.02	0.06	0.05	
SH JINJIANG INTL HOTELS - B									
Industry average 2015–2019 (n = 11)	0.20	0.23	0.21	0.20	0.22	0.40	0.35		2.28%

Table 13Emission intensities accommodation, t CO₂e per room and year.

ton/room/year (CO ₂ e, scope 1–2)	2015	2016	2017	2018	2019	2020	2021	2022
MARRIOTT INTERNATIONAL -CL A	5.16	5.74	5.10	5.19	4.93	3.63	3.94	
LAS VEGAS SANDS CORP								
HILTON WORLDWIDE HOLDINGS IN		2.93	2.68	2.61	2.48	1.69	2.03	2.09
GALAXY ENTERTAINMENT GROUP L								
SANDS CHINA LTD		62.09	65.74	62.25	65.32	37.63	42.24	27.58
MGM RESORTS INTERNATIONAL	19.24	15.86	18.09	16.66	21.44	15.70	16.15	14.22
H WORLD GROUP LTD						0.39	0.39	0.35
INTERCONTINENTAL HOTELS GROUP	3.14	3.05	2.93	2.90	3.03	2.17	2.52	2.72
WYNN RESORTS LTD					36.68			
ACCOR SA	3.38	3.19	3.18	3.00	4.69	3.02	3.58	3.65
WHITBREAD PLC				1.06	1.01	0.64	0.83	0.81
BOYD GAMING CORP								
INDIAN HOTELS CO LTD		12.70	11.39	11.93			7.44	
CHOICE HOTELS INTL INC								0.03
WYNDHAM HOTELS & RESORTS INC				0.36	0.20	0.17	0.20	0.18
SHANGHAI JINJIANG INTERNAT-A								
FOSUN INTERNATIONAL LTD								
HYATT HOTELS CORP - CL A	9.55	8.88	8.48	6.81	7.59	5.06	5.21	
MINOR INTERNATIONAL PCL			10.68	4.17	4.26	3.84	4.53	6.51
HILTON GRAND VACATIONS INC								
WYNN MACAU LTD	134.13	67.25	100.59	91.97	93.29	69.29	75.28	54.42
MGM CHINA HOLDINGS LTD	128.61	122.29	120.76	81.68	82.08	70.80		55.74
BTG HOTELS GROUP CO LTD-A								
GENTING MALAYSIA BHD								
SJM HOLDINGS LTD	84.13	80.62	76.99	73.27	72.64	133.93	679.63	
NAGACORP LTD								
SH JINJIANG INTL HOTELS - B								
Average	48.42	34.96	35.55	25.99	28.55	24.85	60.29	14.02
Median	14.40	12.70	11.04	6.00	6.26	3.73	4.24	3.19

Source: Annual reports, see list of references and Bloomberg

levels necessary to approach net-zero goals. Large tourism firms, in comparison, have grown faster in revenue, have had higher emissions per room, but yielded better emission to value ratios (in 2019). Emission efficiencies in CO₂e per US\$ do not show a clear trend, but appear to have deteriorated between 2015 and 2019 (i.e. emissions per US\$ have increased; Table 12).

Finally, Table 15 illustrates the improvements in emission intensities

needed to stay on track to net-zero under continued growth scenarios of 1.6% (Statista, 2022) and 2.9% (STA, 2017). Even in the least ambitious scenario, in which emissions decline by 90% to mid-century, average decarbonization rates have to be 9%–11%. Again, it does not seem plausible that such progress on emission reductions can be achieved.

Table 14
Emissions and revenue projection for the accommodation sector.

	2019	2030	2040	2050	2030	2040	2050
Growth rate of rooms	Baseline	1.6% (Statista, 2022)			2.9% (STA, 2017)		
Emissions (Mt) (Scope 1 + 2) - low	117	89	75	63	96	91	86
Emissions (Mt) (Scope 1 + 2) - high	140	133	136	139	143	166	192
Revenue (Billions USD)	370	452	632	883	452	632	883
Rooms (million)	17.2	19.0	22.4	26.3	20.5	27.3	36.3
Emission intensity (t/room) (−3.3% CAGR)	6.8	4.7	3.3	2.4	4.7	3.3	2.4
Emission intensity (t/room) (−1.4% CAGR)	8.1	7.0	6.1	5.3	7.0	6.1	5.3

Table 15
Efficiency improvement required for net-zero, accommodation.

Growth rate in rooms	1.6% (Statista, 2022)		2.9% (STA, 2017)	
	Low	High	Low	High
Scenario 1: BAU to 2050				
Emissions (Mt) (Scope 1 + 2)	63	139	86	192
Rooms (million)	26.34	26.34	26.34	26.34
Emissions intensity (t/room/year)	2.37	5.28	2.37	5.28
Scenario 2: 90% emissions reduction by 2050				
Emissions (Mt) (Scope 1 + 2)	11.7	14.0	11.7	14.0
Emissions intensity (t/room/year)	0.45	0.53	0.32	0.39
Annual efficiency improvement rate	9%	10%	10%	11%
Scenario 3: 95% emissions reduction by 2050				
Emissions (Mt) (Scope 1 + 2)	5.9	7.0	5.9	7.0
Emissions intensity (t/room/year)	0.22	0.27	0.16	0.19
Annual efficiency improvement rate	12%	13%	13%	14%
Scenario 4: 99% emissions reduction by 2050				
Emissions (Mt) (Scope 1 + 2)	1.2	1.4	1.2	1.4
Emissions intensity (t/room/year)	0.04	0.05	0.03	0.04
Annual efficiency improvement rate	17%	18%	18%	19%

5. Discussion

5.1. Are net-zero industry goals realistic?

There is much evidence that the global tourism system continues to grow in its emissions, and will continue to do so. The data presented in this paper for three relevant tourism subsectors suggests that large airlines are likely to grow at a rate of 2.1% per year in total emissions, and cruise lines at 4.5% per year. The situation is less clear for accommodation. The Sustainable Tourism Alliance claims a 0.53% per year emission reduction rate (STA, 2017), but data for large firms as presented in this paper point to the opposite, i.e. that emissions continue to increase in absolute terms, at >9% per year for the sample of hotels providing this data. The situation is complex, however, as sales and acquisitions, franchise activities and other factors have considerable importance for emission intensity outcomes in the accommodation sector. Yet, it is evident that in all three subsectors, growth rates appear to exceed the speed of improvements on emission intensities. Data for the 29 large firms studied in this paper – which stand for 32% (air transport), 68% (cruises), and 12% (accommodation) of global emissions of the respective subsectors – thus strongly supports that there will be continued growth in absolute emissions. Compared to annual efficiency improvement rates of between 12% and 20% needed to stay on track to net-zero, global climate goals do not seem realistically achievable.

Findings confirm that airlines face the greatest decarbonization challenges, followed by cruises and hotels. There is further complexity in considering scope 3. Even though firms are only responsible for scope 1–2, they do depend on supply chain inputs. Here, preliminary data suggest that in 2019, scope 3 emissions were 25.3% of scope 1–2 in the aviation sector (with a range of 1.79% and 38.6% between airlines; Gössling et al., 2023); 98.8% in the cruise sector (with a range of 98.2% and 99.3% for Carnival/Royal Caribbean; Humpe et al., 2023-a); and 97.4% in accommodation, with a range of 6.3%–207.3% for n = 10 hotel chains that provide scope 3 data (this research).

Against the findings presented in this paper, the expectation is that tourism will grow in its total emissions and become an increasingly important factor in disruptive climate change. This also means that tourism growth will undermine its own future viability (Scott et al., 2019), unless there is radical change. “Radical”, in this context, means that tourism stakeholders would have to accept higher energy prices that drive efficiencies and new technology adoption, significant reductions in high-emission forms of tourism (yachts, cruises, private and premium class air travel), and, overall, a fundamentally different global geography of tourism (Peeters & Landré, 2011). In this new tourism world, large tourism companies – the drivers of tourism growth through capacity expansion and price competition –, will face difficulties in continuing their business models.

Ultimately, this raises the issue of degrowing tourism, an issue first raised by Hall (2009: 46), who noted that “despite discourses that focus on sustainability and conservation tourism’s contribution to global environmental change have continued to increase”. One and a half decades later, this situation has not improved. To favour qualitative tourism development, a steady-state tourism economy, and critical perspectives on growth agendas in tourism has been suggested by numerous authors, and calls to “reimagine” tourism (Higgins-Desbiolles et al., 2019) have been reinforced by 2018 overtourism debates (e.g. Blázquez-Salom et al., 2019; Fletcher et al., 2019), reverberating through the COVID-19 pandemic (e.g. Gössling et al., 2020). While there is evidence that some small companies have adopted business models aligned with such calls (Hall et al., 2020), there is no indication that large tourism enterprises seek anything but continued volume growth.

5.2. Action or greenwashing?

Notwithstanding the urgency to accelerate mitigation efforts, the evidence is that tourism organizations, large tourism firms, and in particular airlines and cruise lines, continue on a growth trajectory. They also seem to invest growing resources in the creation and spreading of green narratives. This is for example documented for air transport technology ‘myths’ and misleading claims regarding carbon offsetting (Guix et al., 2022; Peeters et al., 2016). Organization such as the World Tourism and Travel Council (WTTC) invest much effort into the communication of efficiency gains and progress on the Sustainable Development Goals including climate change. For example, the WTTC & Oxford Economics (2022) highlights that tourism’s contribution to GDP growth has been 4.3% per year over the period 2010–2019, while emissions grew by 2.4% per year. This seems to imply progress on decarbonization – including during the pandemic years –, and is further underlined by the statement that “emissions reached a peak in 2019” (Fig. 2). Such propositions are not supported by the data presented in this paper, and need to be considered misleading.

There are other issues with the WTTC & Oxford Economics (2022) narrative. In climate change terms, total contributions determine global warming outcomes – efficiency gains are irrelevant. The WTTC does not provide data on total emissions, however. There are further issues with the use of emission intensity indicators that are also pertinent to this research. For example, when inflation is high, this will lead to higher annual improvement rates for emission intensities. Notionally, the sector would seem to decarbonize, as the growing volume of money in circulation leads to a ‘dilution’ of emissions per unit of GDP. Yet, net of

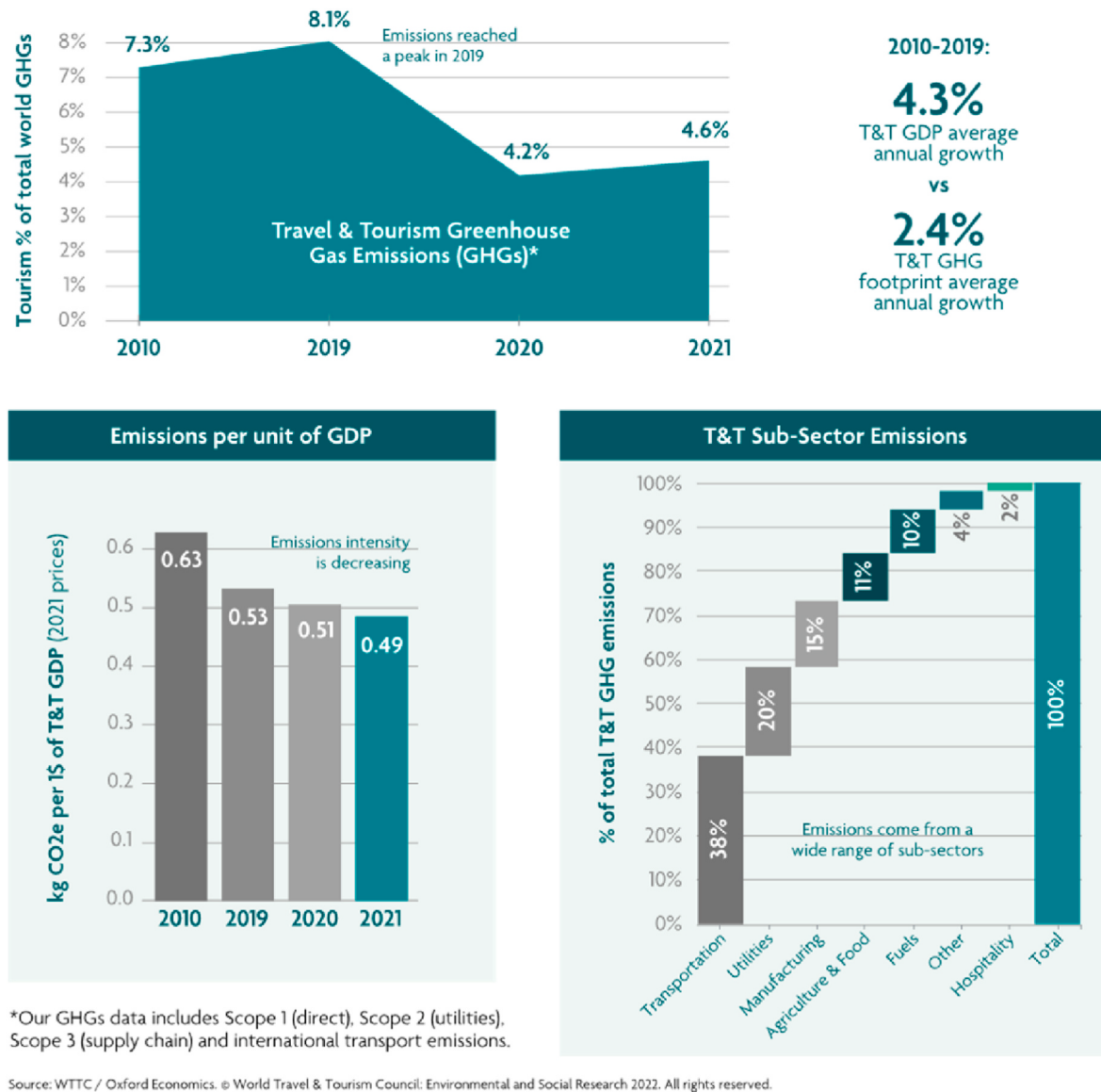


Fig. 2. Decarbonization progress as presented by the tourism industry.
Source: WTTC & Oxford Economics (2022)

inflation, emission intensities may worsen. All industry indicators and benchmarks should thus be contrasted with the development of total emission trajectories, but these are often missing (see also WTTC and Greenview, 2022). As highlighted earlier, this is further complicated by non-CO₂ emissions associated with air transport that also make significant, but unaccounted for, contributions to climate change.

Green narratives are also evident at the firm level. For example, Badvertising and Adfree Cities asked the UK Competition and Markets Authority to take action against easyJet adverts “using speculative promises about new technologies in the future in order to sell more polluting flights today” (Badverts, 2022: no page). In the US, a class-action lawsuit concluded that Delta Air Lines should “pay damages to customers for misrepresenting itself as a carbon-neutral airline in marketing campaigns” (The Washington Post, 2023, no page). In the Netherlands, a civil suit against KLM has been admitted in June 2023 for allegedly misleading consumers about the airline’s environmental credentials (Reuters, 2023). These examples illustrate that claims regarding mitigation are legally false, leading to litigation and reputational damages for the firms involved.

The findings presented in this paper do foreshadow further

reputational and litigation risks. As highlighted in the context of air transport (Guix et al., 2022), greenwashing strategies may include false statements, deflections that present “solutions” without discussing their implications, unsubstantiated assertions, vague declarations intended to be misunderstood, irrelevant information that distracts from specific issues, the downplaying of impacts, and impressions of third-party endorsement that does not exist. These are also evident in the cruise sector (de Jong et al., 2020) and the accommodation sector (Font et al., 2012; see also Bloomberg, 2022). Firms thus need to consider whether their ambitions should rather lie with measurable progress on net-zero.

5.3. Benchmarks for measurable progress

Benchmarks to assess emission intensities have been presented for destinations such as New Zealand or Norway, revealing emission to revenue values of 0.19–0.24 kg CO₂ per US\$ for tourism in general, and 0.87–0.89 kg CO₂ per US\$ for aviation (Sun et al., 2022; Sun & Higham, 2021). Data for large firms as presented in this paper indicates that subsector averages for large tourism firms are similar for hotel chains (at 0.22 kg CO₂ per US\$), but much higher for aviation, at 1.24 kg CO₂ per

US\$. The analysis also reveals considerable differences between companies. The range for aviation between the “best” and “worst” performing airline suggests a range of 0.67 kg CO₂ per US\$ (ANA) to 1.35 kg CO₂ per US\$ (Cathay Pacific), i.e. a 100% difference between firms. Data available for three cruise lines suggests kg CO₂ to US\$ ratios of 0.42 (Norwegian), 0.44 (Royal Caribbean) and 0.52 (Carnival); a 24% difference. The most considerable ranges have been observed for hotel chains, with a range from 0.01 kg CO₂ per US\$ (SJM Holdings) to 1.04 kg CO₂ per US\$ (Fosun International), i.e. a difference by two orders of magnitude. While this may be explained by specific structures (franchises, casinos), findings also reveal that specific hotel types will face greater challenges under regulation targeting scope 1–2 emissions.

Several indicators have been developed in this paper that can serve as benchmarks, such as emissions per US\$, RPK, passenger, or room. The most relevant one describes emission intensities, as this indicator can also be used to provide advice to companies on net-zero alignment. As outlined, the most significant emission reductions have to be achieved in the near-term future to 2030, and all companies have to reach net-zero by mid-century. This goal can be defined as a reduction from current total CO₂ emissions by at least 90%. Under this approach, a hypothetical company generating emissions of 1 kg CO₂ per US\$ in 2024 would have to reduce its emissions to 0.59 kg CO₂ per US\$ in 2030, 0.38 kg CO₂ per US\$ in 2035, 0.24 kg CO₂ per US\$ in 2040, 0.16 kg CO₂ per US\$ in 2045 and 0.1 kg CO₂ per US\$ in 2050 (Table 16). This corresponds to an annual efficiency improvement by 8.48% in a scenario without revenue growth. Should the company grow in its revenues at any rate (1%–6% per year in Table 16), this will influence necessary net-zero annual efficiency improvements, in kg CO₂ per US\$ ratios. As illustrated in Table 16, a growth rate of 6% per year will require an average annual efficiency improvement of 13.7%.

As all companies have different starting points (CO₂ to US\$ ratios), individual emission efficiency indicator timelines to 2050 can be developed under consideration of expected growth rates. In an annual review, the company can easily determine whether it is on track to net-zero. Notably, such timelines may also be developed for sub-sector specific indicators, such as emissions per RPK, per passenger, or per room, to provide additional insight. For example, these more specific indicators may also be developed for individual flight or cruise routes, or individual hotels within a chain. Longitudinal assessments can also contribute to an understanding of seasonality effects.

5.4. Policies for competition on efficiency

The dataset produced for this research highlights two important inroads for emission reductions. One relevant finding is that there are considerable differences in emission intensities between companies. This provides an inroad for competition on efficiency. Should tourism firms be rated and ranked - for instance, in the form of the EU white appliances label with a colour scheme ranging from green = efficient to red = inefficient -, this may have considerable influence on consumer choices. As a few firms have managed to reduce their absolute emissions, i.e. to achieve improvements in emission intensities that outpace their

growth rates, this provides a basis for policies that support such ambitions. For example, carbon taxes in any form that are proportional to the environmental impact of emissions – at an order of at least US\$200 per ton (Tol, 2023) – increase pressure on the more polluting companies.

Carbon taxes also have relevance in the context of scope 3 emissions. For example, to improve their scope 1–2 performance, hotel chains may choose to strategically outsource services with a high carbon-content. This would increase scope 1–2 emissions in smaller companies not subject to reporting or climate policies. Essentially, such mechanisms are already in use by chains operating on a franchise basis. Sector-wide carbon taxation can prevent such strategies, but they require regulation beyond current policies.

Other policies may include slot distribution at airports or building permits assigned on the basis of efficiency-based criteria. While some of these mechanisms need to be implemented by policymakers at national or local scales, some can also be introduced by firms, such as ports or airports. These options need to be more systematically explored – and urgently so – to increase pressure on large tourism firms to engage with mitigation.

6. Conclusions

There is considerable urgency to reduce emissions to net-zero over little more than 25 years. Tourism accounts for an estimated 8% of global CO₂ and is particularly relevant in this ambition, as the sector continues to grow. This research has looked into a sample of 29 large tourism companies belonging to three subsectors (aviation, cruises, hotels) that together account for about 13% of global tourism's emissions (scope 1–2). Data for 2015–2019 suggests that while companies show significant annual progress on improving emission intensities, overall emissions continue to grow. None of the subsectors is on track to net-zero, illustrating that continued growth in tourism cannot be aligned with the steep emission reductions necessary for net-zero goals.

As the tourism industry has repetitiously presented data on emission intensity improvements, results emphasize the necessity to move from relative to absolute measures of emissions in company communications. This is equally true for sector organizations such as the WTTC. All tourism firms have an obligation to reduce emissions to net-zero within 25 years. As this is unachievable under continued growth scenarios, new business models need to be developed. To aid firms to stay on track, a novel system of emissions to revenue benchmarks for the period 2024–2050 has been presented. These can be used to determine whether a company decarbonizes at a speed that is aligned with net-zero goals.

The discussion in this paper also points at potential issues that need to be resolved. For example, a business may reduce its scope 1–2 emissions by outsourcing specific parts of its operations to the supply chain. High inflation rates may suggest that a business is decarbonizing at speed, though it may be less efficient if considering real US\$ developments. Future assessments of efficiency improvements should thus be measured in constant rather than nominal US\$. Findings also show that it is very difficult to assess the situation in hotels, where “progress” may depend on a wide range of factors, such as hotel types and services offered (e.g., casinos).

Further research is needed to address these and other uncertainties. The overall findings are clear, however: Large tourism firms need to move away from communications falsely suggesting that they are decarbonizing, also because these represent growing litigation and reputation risks. Rather, they need to consider far-reaching operational changes in order to bring down emissions rapidly while maintaining revenue levels. Business-as-usual is now less of an option than it has ever been. There is a simultaneous need to consider the implications, as tourism will become increasingly less viable in many regions of the world. Large firms should begin to prepare for a different tourism world, acknowledging that market-based instruments such as carbon taxes and other policies will be necessary to bring down emissions.

Table 16
Emission efficiency improvement timelines for different revenue growth rates.

kg CO ₂ /US\$ Revenue growth	Year						Efficiency gains p.a.
	2024	2030	2035	2040	2045	2050	
0.0%	1.00	0.59	0.38	0.24	0.16	0.10	8.5%
1.0%	1.00	0.55	0.34	0.21	0.13	0.08	9.4%
2.0%	1.00	0.52	0.30	0.18	0.10	0.06	10.3%
3.0%	1.00	0.49	0.27	0.15	0.08	0.05	11.1%
4.0%	1.00	0.46	0.25	0.13	0.07	0.04	12.0%
5.0%	1.00	0.44	0.22	0.11	0.06	0.03	12.8%
6.0%	1.00	0.41	0.20	0.10	0.05	0.02	13.7%

Credit author statement

Stefan Gössling: Conceptualization, Methodology, Writing- Original draft preparation, Visualization. Andreas Humpe: Conceptualization, Methodology, Data curation, Analysis. Ya-Yen Sun: Conceptualization, Data curation.

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Impact statement

A comparably small number of the world's largest tourism firms accounts for a significant share of the sector's overall contributions to climate change. This paper studies the annual reports of 29 firms responsible for 13% of global tourism CO₂. Results show that while many firms have become more efficient (per dollar of revenue), their overall emissions continue to grow. As further growth is expected, calculations suggest that decarbonization rates of 12%–20% per year would be necessary for these firms to stay on track to net-zero emissions by 2050. This is not realistic. The paper is the first to detail emission developments for large firms; to calculate the future decarbonization rates needed for these firms to reach net-zero; and to discuss the implications of the findings against the background of policy implications and the need for new business models.

Declaration of competing interest

None.

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