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# 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 $CO_2$) 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" $CO_2$-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 Schell, Coal India and Gazprom, each emit in excess of 1 Gt $CO_2$. Cumulatively, they account for 3.87 Gt $CO_2$ (scope 1–3), representing more than 10% of global emissions of 36.5 Gt $CO_2$ (IEA, 2023a, pp. 1900–2022). The ten largest MNEs emit 20% of global $CO_2$ 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 Quantas (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 $CO_2$ 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 $CO_2$, 700 Gt $CO_2$ and 1150 Gt $CO_2$ (67% chance; IPCC, 2021: 29). Fig. 1 shows the development of $CO_2$ 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 $CO_2$ 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 $CO_2$) 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 $CO_2$ 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 (WTTC-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 (Cadarso 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 $CO_2$e per dollar of final demand" in 2013, and hence significantly higher than the global average of 0.75 kg $CO_2$e 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

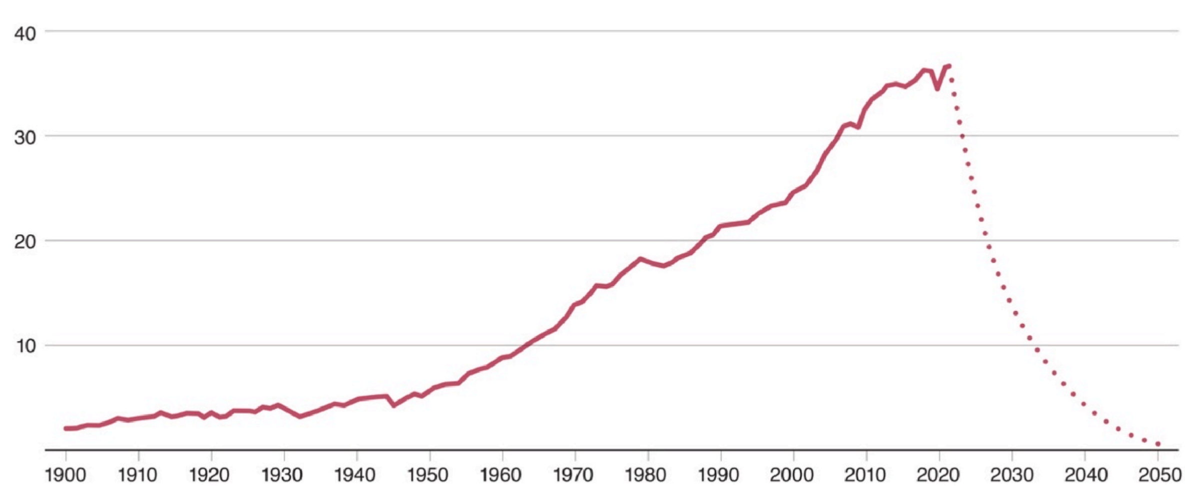


**Fig. 1.** $CO_2$ emission growth and necessary decarbonization to 2050.
Source: based on IEA (2023a), IPCC (2021)

Zealand, tourism is 0.24 kg $CO_2$ per US$ of revenue, and aviation 0.87 kg $CO_2$ per US$ (Sun & Higham, 2021). In Norway, the value is 0.19 kg $CO_2$ per US$ of revenue for tourism, and 0.89 kg $CO_2$ 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-$CO_2$ 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 $CO_2$ 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 $CO_2$ per US$ of revenue (all subsectors) as well as kg $CO_2$ per RPK (airlines), kg $CO_2$ per passenger (cruises) and kg $CO_2$ per room (hotel chains). Indicators were calculated by dividing revenue in million US$ by total $CO_2$ 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 $CO_2$ for air transport and cruises, and $CO_2$e for accommodation (this includes emissions of carbon dioxide, methane and nitrous oxide). Non-$CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$/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 $CO_2$ 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 average.

**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).

### 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 $CO_2$, respectively. There are several other airlines producing in the order of 30 Mt $CO_2$ 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 $CO_2$ in 2015 to 332 Mt $CO_2$ 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 $CO_2$ per RPK, or 0.72 kg $CO_2$ per US$ of revenue,

**Table 2**
Scope 1–2 emissions for airlines, Mt $CO_2$.

| 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 $CO_2$ 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 $CO_2$ in 2050. In this scenario, accumulated emissions between 2024 and 2050 will exceed 30 Gt $CO_2$, 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-$CO_2$ 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 $CO_2$ in 2015 to 15.6 Mt $CO_2$ 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 $CO_2$ per US$ of revenue (Carnival) and 0.44 kg $CO_2$ 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 $CO_2$ per US$ of revenue (Carnival) and 1.69 kg $CO_2$ 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 $CO_2$ in 2015 to 804 kg $CO_2$ in 2019, the amount of emissions caused by the cruise is rather in the order of 1.6 t $CO_2$ (Humpe 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 $CO_2$ per RPK, air travel adds about 120 kg $CO_2$ per 1000 km of distance. This can again double the amount of $CO_2$ involved in a cruise. Data confirms that cruises are the most carbon-intense 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 $CO_2$ 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 $CO_2$ (scope 1–2) and revenues of US$50.5 billion in 2019 will grow to 70.9 Mt $CO_2$ 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 $CO_2$ per US$ in 2019 to 0.23 kg $CO_2$ per US$ in 2050, and per passenger emissions from 827.3 kg $CO_2$ per trip in 2019 to 489.3 kg $CO_2$ 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 $CO_2$ 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 $CO_2$ 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 $CO_2$ in 2015 to 17.3 Mt $CO_2e$ 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 $CO_2e$ per US$) increased from 0.20 kg $CO_2e$ per US$ in 2015 to 0.22 kg $CO_2e$ 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 $CO_2e$ per US $ (SIM Holdings) to 1.04 kg $CO_2e$ 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 $CO_2e$ 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 $CO_2e$ per US$ during the period 2015–2019, but these went up to 0.3 kg $CO_2e$ 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 $CO_2e$ per room per year (Wyndham; though this may be a result of changes in reporting), to 93.3 t $CO_2e$ per room per year (Wynn Macau) in 2019. Median data for 2019, at 6.26 tons of $CO_2e$ per room and year, is close to the extrapolated average value of 6.8 t $CO_2e$ per room and year presented by STA (2017). While the data also suggests

**Table 10**
Scope 1–2 emissions for hotels, thousands of metric tons $CO_2e$.

| Thousand ton $CO_2e$ | 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 12**
Emission intensities accommodation, kg $CO_2e$ 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 13**
Emission intensities accommodation, t $CO_2e$ per room and year.

| ton/room/year ($CO_2e$, 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 $CO_2e$ 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

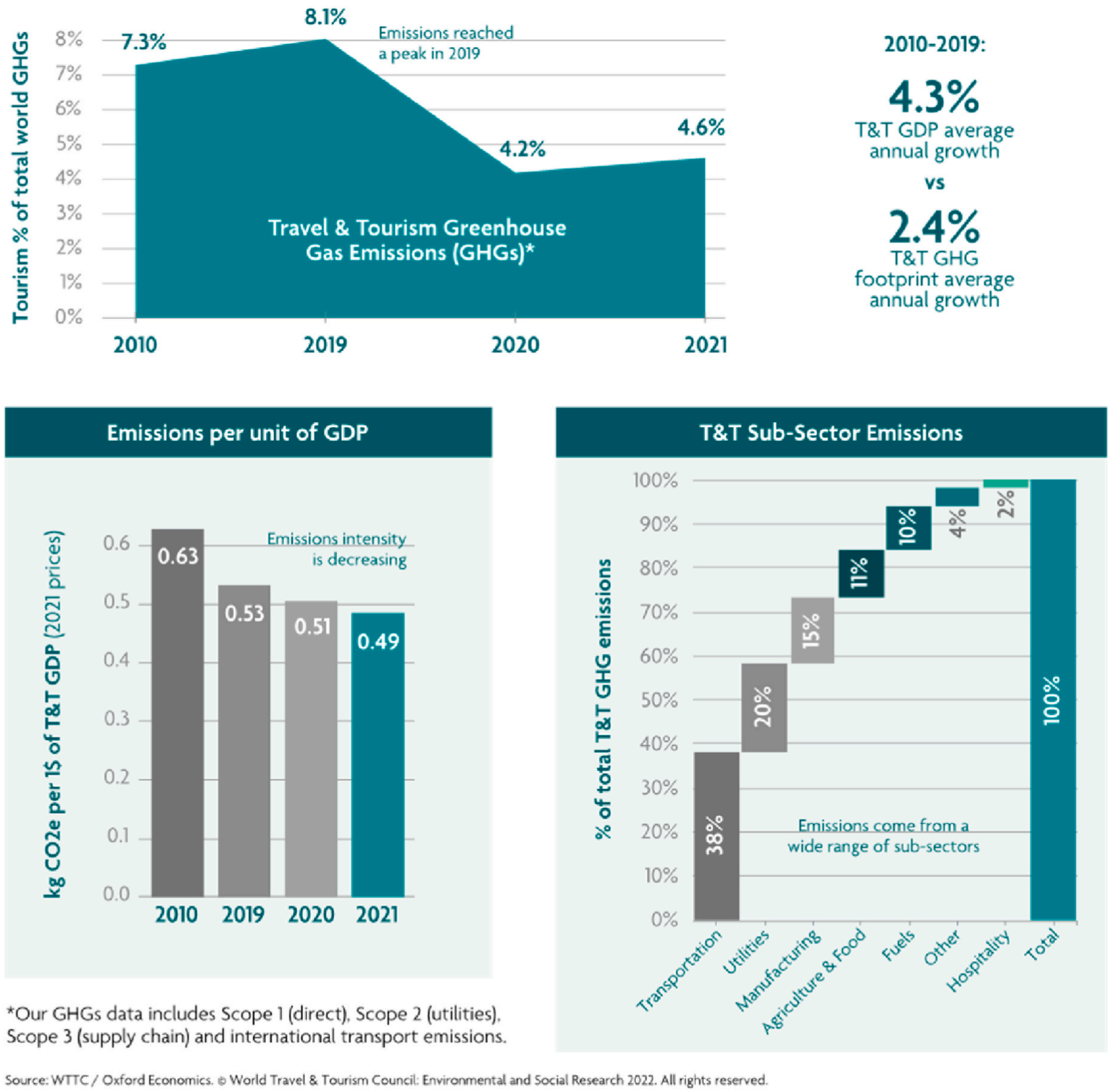


**Fig. 2.** Decarbonization progress as presented by the tourism industry.
Source: WTTC & Oxford Economics (2022)

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-$CO_2$ 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 $CO_2$ per US$ for tourism in general, and 0.87–0.89 kg $CO_2$ 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 $CO_2$ per US$), but much higher for aviation, at 1.24 kg $CO_2$ 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 $CO_2$ per US$ (ANA) to 1.35 kg $CO_2$ per US$ (Cathay Pacific), i.e. a 100% difference between firms. Data available for three cruise lines suggests kg $CO_2$ 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 $CO_2$ per US$ (SJM Holdings) to 1.04 kg $CO_2$ 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 $CO_2$ emissions by at least 90%. Under this approach, a hypothetical company generating emissions of 1 kg $CO_2$ per US$ in 2024 would have to reduce its emissions to 0.59 kg $CO_2$ per US$ in 2030, 0.38 kg $CO_2$ per US$ in 2035, 0.24 kg $CO_2$ per US$ in 2040, 0.16 kg $CO_2$ per US$ in 2045 and 0.1 kg $CO_2$ 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 $CO_2$ 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 ($CO_2$ 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.

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

| kg $CO_2$/US $ | Year | | | | | | Efficiency gains p.a. |
|---|---|---|---|---|---|---|---|
| Revenue growth | 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% |

## 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 $CO_2$ 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.

## Credit author statement

Stefan Gössling: Conceptualization, Methodology, Writing- Original draft preparation, Vizualisation. 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 $CO_2$. 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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