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Global carbon emissions and decarbonization in 2024

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Global CO_2 emissions in 2024 increased 0.9% on the previous year, totalling 36.3 Gt CO_2. These ongoing emissions further deplete remaining carbon budgets, with some estimates suggesting the 1.5 °C budget will be surpassed within the next 5 years — and may have been already.

Global average CO_2 emissions exhibit a long-term increase, averaging 2.2% yr^{-1} since 1960 (ref. 1). Within this longer-term change is interannual variability arising from factors such as economic activity, energy prices and policy changes, as observed during the COVID-19 pandemic when emissions dropped by 6.0% (ref. 2). While emissions growth has subsequently slowed and renewable energy production expanded (Fig. 1), ongoing CO_2 emissions continue to eat away at the remaining carbon budget to achieve Paris Agreement targets. Thus, it is crucial that decarbonization efforts reach a critical transition such that future emissions decline at pace, especially considering that 2024 global temperatures were the warmest on record.

Here, we document global CO_2 emissions and avoided CO_2 emissions from renewable energy development (Scope 4 emissions) in 2024. We use data from the Carbon Monitor project (https://carbonmonitor.org), which integrates sector-specific activity proxies across electricity production (58 countries), industrial output (73 countries), traffic (406 cities), aviation, maritime transport and residential fuel use (206 countries).

Global CO_2 emissions

Globally averaged CO_2 emissions were at an all-time high in 2024. Indeed, emissions from fossil fuel combustion and cement production totalled 35.3 Gt CO_2 in 2019 (+0.8%), 33.3 Gt CO_2 in 2020 (−6.0%), 35.2 Gt CO_2 in 2021 (+6.0%), 35.9 Gt CO_2 in 2022 (+1.8%), 35.9 Gt CO_2 in 2023 (+0.1%), culminating in a record 36.3 ± 0.3 Gt CO_2 in 2024 (+0.9 ± 1.0%) (Fig. 1). This 2024 total is broadly in keeping with the +0.8 ± 1.1% increase predicted by the Global Carbon Project based on the data from January to August[1]. Thus, the positive trajectory or rebounding of emissions since 2020 continues, signalling that emissions have not yet peaked or plateaued as hoped.

The sectoral distribution of global CO_2 emissions in 2024 remains broadly consistent with past years. The power sector contributes 38.7% of the total (up from 38.5% in 2023), followed by industry at 28.5% (down from 28.9%), ground transport at 18.7% (up from 18.6%), residential at 9.4% (stable), international shipping at 1.9% (down from 2.0%), international aviation at 1.8% (up from 1.7%) and domestic aviation at 1.0% (stable). Although sectoral shares of the total remain relatively stable, absolute emissions within each sector highlight greater fluctuations. Notably, emissions from domestic and international aviation increased by 3.7% and 9.9% relative to 2023, respectively, while international shipping fell by 4.2%. These relatively small changes all contribute to the total incremental emission growth.

As with the sectors, the country-level breakdown of leading emitters also remains relatively similar. The top five emitters — China, USA, India, European Union (excluding UK) and Russia — still account for 23.2 Gt CO_2 (64%) of total emissions in 2024. Although 2020 saw an anomalous drop due to the pandemic — with a subsequent rebound in 2020–2022 — specific emissions changes within these nations reveal more complicated patterns. Some nations/regions, for instance, exhibit relatively stable year-on-year emission increases, as in India (rising from 2.5 Gt CO_2 in 2019 to 3.0 Gt CO_2 in 2024, with year-on-year rates of +9.0% in 2023 and +4.5% in 2024) and Russia (increasing from 1.5 Gt CO_2 in 2019 to 1.7 Gt CO_2 in 2024, with year-on-year rates of +2.6% in 2023 and +3.5% in 2024). By contrast, others experience relatively stable year-on-year decreases, as in the EU (decreasing from 2.7 Gt CO_2 in 2019 to 2.4 Gt CO_2 in 2024, with year-on-year rates of −9.8% in 2023 and −3.2% in 2024) and UK (falling from 344 Mt CO_2 in 2019 to 318 Mt CO_2 in 2024, with year-on-year rates of −4.2% in 2023 and −2.8% in 2024). For other countries, the changes are lot more variable, including China (varying from 10.5 to 11.3 in 2019–2024, with year-on-year rates of −1.3% in 2022, +2.5% in 2023, and −0.3% in 2024) and the USA (varying from 4.6 to 5.0 Gt CO_2 during 2019–2024, with year-on-year rates of +3.2% in 2022, −2.3% in 2023, and +1.5% in 2024). These changes highlight the varied pace of energy transitions across different regions.

Remaining permissible emissions

These growing emissions continue to deplete the carbon budgets necessary to constrain anthropogenic warming to meet the Paris Agreement targets. IPCC-derived budgets outline that 400 Gt CO_2 can be emitted from 2020 to maintain warming below 1.5 °C at 67% likelihood[3], 195 Gt CO_2 of which had been consumed by the end of 2024 (including CO2 emissions from fossil fuel combustion and land use changes; Fig. 1,

Key points

- Global emissions averaged 99.3 Mt CO_2 per day, with the largest growth coming from India and Russia, and a slight reduction from China.
- Global non-fossil energy development grew 6.2%, corresponding to an estimated 9.8 Gt CO_2 of Scope 4 (that is, avoided) emissions in 2024.
- 0–205 Gt CO_2 remains of the carbon budget to limit warming to 1.5 °C, suggesting permissible emissions have already been exceeded or could be depleted within 5.1 years; 860–955 Gt CO_2 remains of the 2 °C budget, which could be depleted within 21.3–23.7 years (at 67% likelihood).

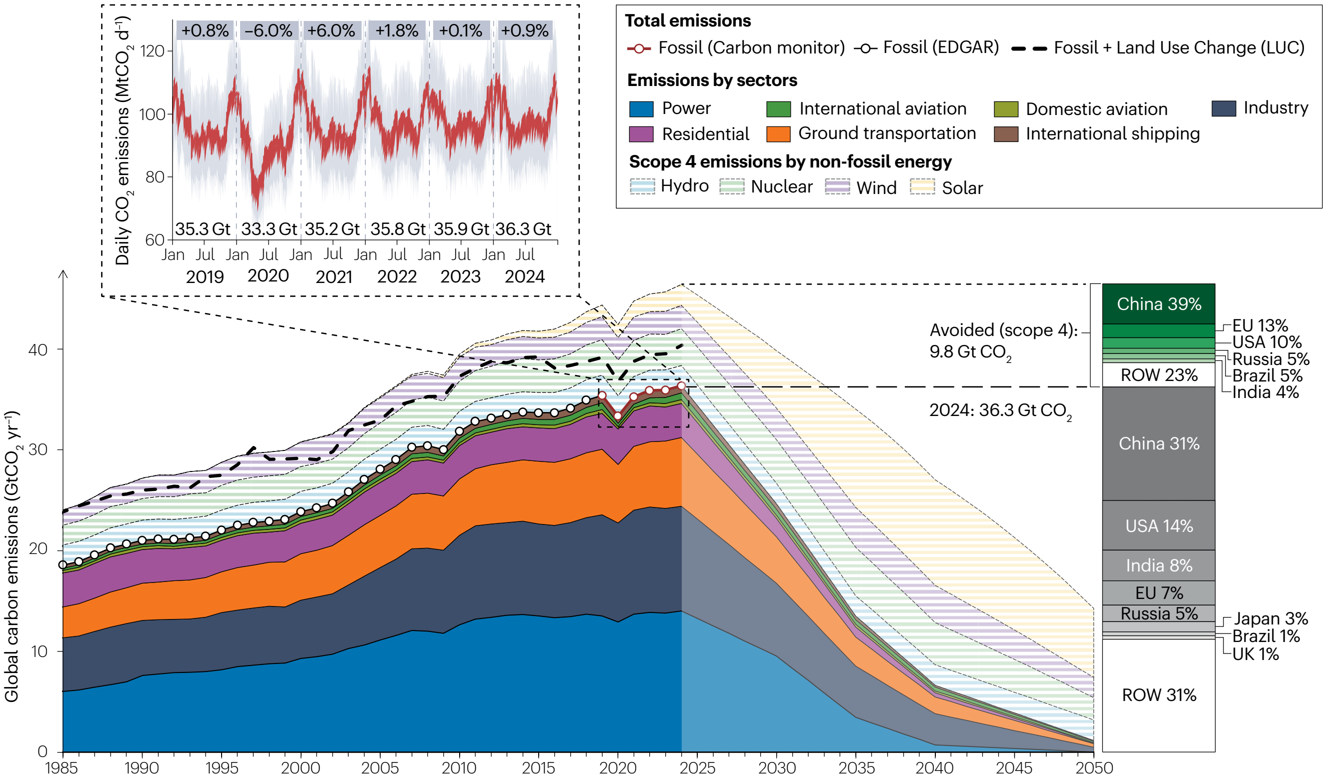

Fig. 1 | Global CO2 emissions and projections 1985–2050. Historical[8] and projected CO_2 emissions from fossil fuel combustion and cement production ('Fossil CO_2') by sector (solid colours), and historical and projected Scope 4 emission avoidance by renewable energy type (hatched colours). The inset displays daily near-real-time CO_2 emissions since 2019 from the Carbon Monitor project with accompanying absolute emissions and year-on-year changes; values are revised from earlier estimates[2,9] owing to updated activity data and methodologies[10]. The bar to the right displays 2024 emissions (greyscale) and Scope 4 avoided emissions (green shades) by country. Global CO_2 emissions fluctuate year to year but continue a positive trajectory, rapidly dwindling remaining carbon budgets.

black dashed line). This consumption represents 49% of permissible emissions, the remaining 51% (205 Gt CO_2) of which would last ~5.1 years if emission rates continue. By contrast, the 1.5 °C budget at 83% likelihood is 300 Gt CO_2 (ref. 3, 65% has already been consumed, the remaining 35% (105 Gt CO_2) is estimated to be exhausted within ~2.6 years. Other estimates suggest lower 1.5 °C permissible emissions[4], with only 60 Gt CO_2 available from January 2023 at 66% likelihood. Given that 80 Gt CO_2 have been consumed since 2023, this budget has already been exceeded by 133%, aligning with findings that warming might already have reached 1.5 °C (ref. 5).

The carbon budget for 2 °C warming is larger and, hence, will take longer to consume. Based on the IPCC budgets, for example, 1,150 Gt CO_2 can be emitted to stay within 2 °C at 67% likelihood. A total of 17% of this budget has been used, the remaining 83% (955 Gt CO_2) of which could be depleted within 23.7 years if emissions remain unchanged. At an 83% likelihood, the 2 °C budget lowers to 900 Gt CO_2 such that 22% has been consumed; the remaining 78% (705 Gt CO_2) would last ~17.5 years. The non-IPCC budgets[4] indicate 940 Gt CO_2 could be emitted to keep warming within 2 °C at 66% likelihood. Of this budget, 860 Gt CO_2 remains, which would last a further ~21.3 years.

Global renewable developments

Given the rapid dwindling (or complete use of) remaining carbon budgets, rapid decarbonization is required. Tracking Scope 4 emissions[6] — prevented CO_2 emissions associated with the adoption of non-fossil energy sources — allows progress to be assessed in this regard. Since 1985, these avoided emissions due to hydro, nuclear, wind and solar electricity production amount to 224 Gt CO_2, gradually increasing over time; projections suggest a further 682 Gt CO_2 emissions could be avoided between 2025 and 2050, primarily from solar and wind (Fig. 1).

Matching the longer-term positive trend in non-fossil energy generation, Scope 4 emissions also increased in 2024. Specifically, global Scope 4 emissions increased by 7.3% (661 Mt CO_2) relative to 2023, thereby averting an additional 9.8 Gt CO_2 emissions. Contributing to these changes were 4.0%, 1.5%, 7.6% and 24.9% increases in hydro, nuclear, wind and solar, respectively. Focusing on the big five emitters, growth is observed across all non-fossil markets. For example, China witnessed a 14.5% (485 Mt CO_2) increase in Scope 4 emissions driven by robust growth in wind (13.2%; 124 Mt CO_2), solar (37.4%; 233 Mt CO_2) and hydropower (9.1%; 120 Mt CO_2), but minimal changes in nuclear (1.5%; 7 Mt CO_2). India experienced 8.7% (31 Mt CO2) total growth in Scope 4 emissions associated with expansion in wind (9.2%; 7 Mt CO_2), solar (13.3%; 14 Mt CO_2), and hydropower (3.8%; 5 Mt CO_2). Although total Scope 4 emissions changes across the USA are more meagre at 6.9% (64 Mt CO_2), solar contributions increased 36.9% (48 Mt CO_2); changes for wind, nuclear and hydropower were 6.9% (16 Mt CO_2), 0.3% (1 Mt CO_2) and −0.8% (−1 Mt CO_2), respectively. In the EU and Russia, Scope 4 emission changes from 2023 to 2024 were more modest still, reaching 1.0% (13 Mt CO_2) and 2.5% (13 Mt CO_2), respectively.

Summary

Detailed and near-real-time monitoring of CO_2 emissions reveals that worldwide CO_2 emissions reached a record 36.3 Gt CO_2 in 2024, marking a 0.9% increase from 2023. Although emission growth has slowed since 2021, the uptick in 2024 concerningly suggests that global emissions have yet to reach their peak: rising emissions in India and Russia and a rebound in the USA demonstrate this point. Although energy transitions, particularly those led by China, have contributed to the observed declines in regional emissions, these changes are not large enough to offset increases in other regions and sectors, including the heavy industry and aviation sectors[7]. In this context, the carbon budget for limiting warming to 1.5 °C might already have been exhausted by the end of 2024, with the remaining budget for staying below 2 °C also rapidly diminishing. The window of opportunity for meeting more ambitious climate targets is closing quickly, underscoring the urgent need for robust mitigation measures at COP30.

Data availability

Daily CO_2 emissions by sector and by country from 1st January 2019 onwards are available from the Carbon Monitor database (https://carbonmonitor.org). Global annual CO_2 emissions from 1970 to 2018 were obtained from the Emissions Database for Global Atmospheric Research (EDGAR) (https://edgar.jrc.ec.europa.eu/emissions_data_and_maps). Data on global land-use change emissions are available from the Global Carbon Budget 2024 (https://doi.org/10.18160/gcp-2024). Electricity production data by energy source from 1985 to 2023 are available from Statistical Review of World Energy 2024, Energy Institute (EI) (https://www.energyinst.org/statistical-review/resources-and-data-downloads), and emission factors are estimated by using sectoral emission data from EDGAR and thermal generation data by EI. Electricity generation and emission factors in 2024 are estimated based on daily electricity production data from the Carbon Monitor Power (https://power.carbonmonitor.org/), which encompass power generation information from 58 countries and accounts for approximately 80% of global electricity production. Projections of electricity generation by sources and emissions for 2025–2050 are sourced from IEA World Energy Outlook 2024 (https://www.iea.org/reports/world-energy-outlook-2024), and emission factors of electricity generation are calculated based on the projected thermal production and projected power emissions.

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Competing interests

The authors declare no competing interests.