Submission to the technical phase of the Global Stocktake 2021-2023

Performance distributions to assess collective progress in reducing greenhouse gas emissions

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Disclaimers

This submission is based on the discussion paper: Nascimento, L. *et al.* (2023) *Greenhouse gas emission distributions: Informing the Global Stocktake (2021-2023)*. German Environment Agency. Available at: https://www.umweltbundesamt.de/publikationen/greenhouse-gas-emission-distributions.

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Summary

The Global Stocktake plays an important role in the efforts to reduce global greenhouse gas emissions by synthesising knowledge about the state of global climate action and advising on future steps to scale up mitigation efforts. The outcome of the Global Stocktake must clearly communicate the urgency to improve national mitigation efforts. Ideally, it would also provide detailed recommendations on how to do so.

In this submission, we illustrate how the Global Stocktake can complement existing analyses of greenhouse gas emissions using performance distribution visualisations (Figure 1). This approach shows that not all countries are equal while simultaneously maintaining the Global Stocktake requirement of assessing collective progress. It helps to define the performance of laggard (or frontrunner) countries and visualise sectoral progress.

The performance distribution of annual change rates in the past five years, for example, shows that absolute emissions are still increasing in most countries (Figure 1). The median and mean emissions trends are woefully insufficient to meet the temperature goal of the Paris Agreement. Achieving the necessary average global emission decline implies that some countries will need to reduce emissions faster than the global average to account for different responsibilities and capabilities. To date, no country has emission decline rates faster than the global value range needed. However, 42 countries had declining emissions in the past five years and some present a decline within the Paris-compatible global range. Identifying enabling conditions for these decline rates could support accelerating mitigation efforts (Boehm *et al.*, 2022).

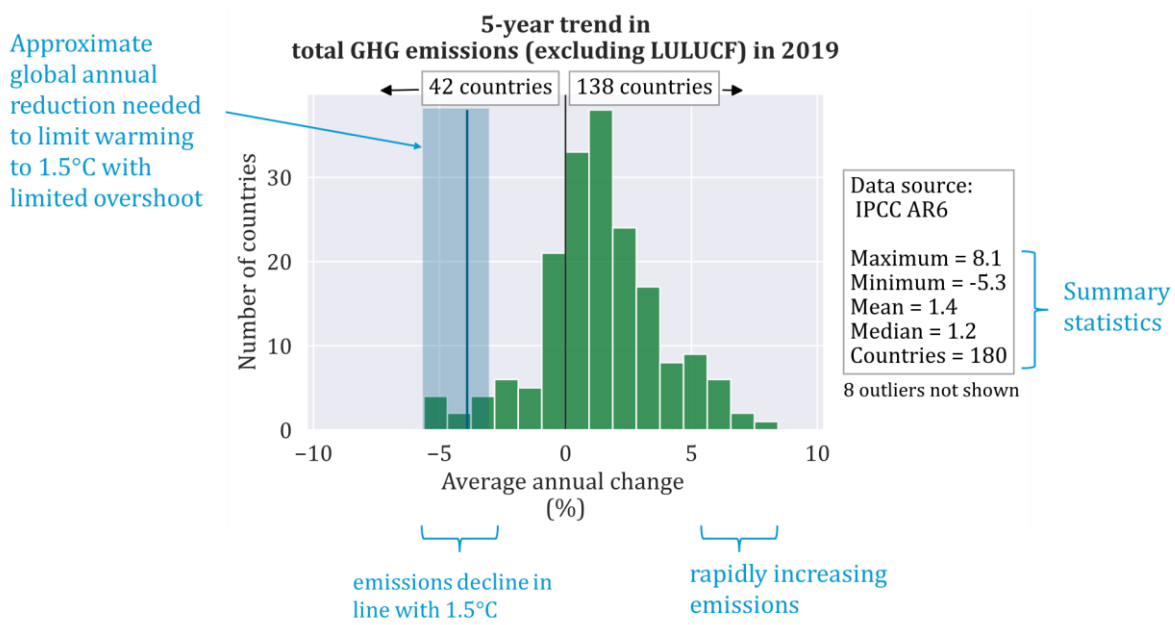

Figure 1: Performance distribution showing average five-year annual change rate of total emissions across 180 countries between 2015 and 2019 (excluding land use, land-use change and forestry). Annual reduction median and range (5-95th percentile) needed between 2019 and 2030 calculated based on mitigation scenarios compatible with 1.5°C warming with no or limited overshoot (IPCC, 2022).

Similar analyses can also be prepared on a sectoral level, including non-emission indicators, once sectoral goals or benchmarks are available. Making these performance distributions public also allows countries to evaluate their own trends and situate their efforts in the global context. Performance distributions would help to fulfil the desired functions of the Global Stocktake as a pacemaker, ensuring accountability, driving ambition and providing guidance and signal (Jeffery *et al.*, 2021).

Key findings

We find that transport- and industry-related greenhouse gas emissions per capita increased in over half of the 180 countries examined in the past twenty years (positive median increase in Figure 2 – bottom). In the transport sector, only one-quarter of the countries have 2019 emissions per capita below 2000 levels, in contrast to slightly over one-third in industry. However, in the energy supply sector, we observe that most countries have 2019 per capita emissions below 2000 levels. In addition to energy supply, building and agriculture emissions per capita are below 2000 levels in over half of the countries studied.

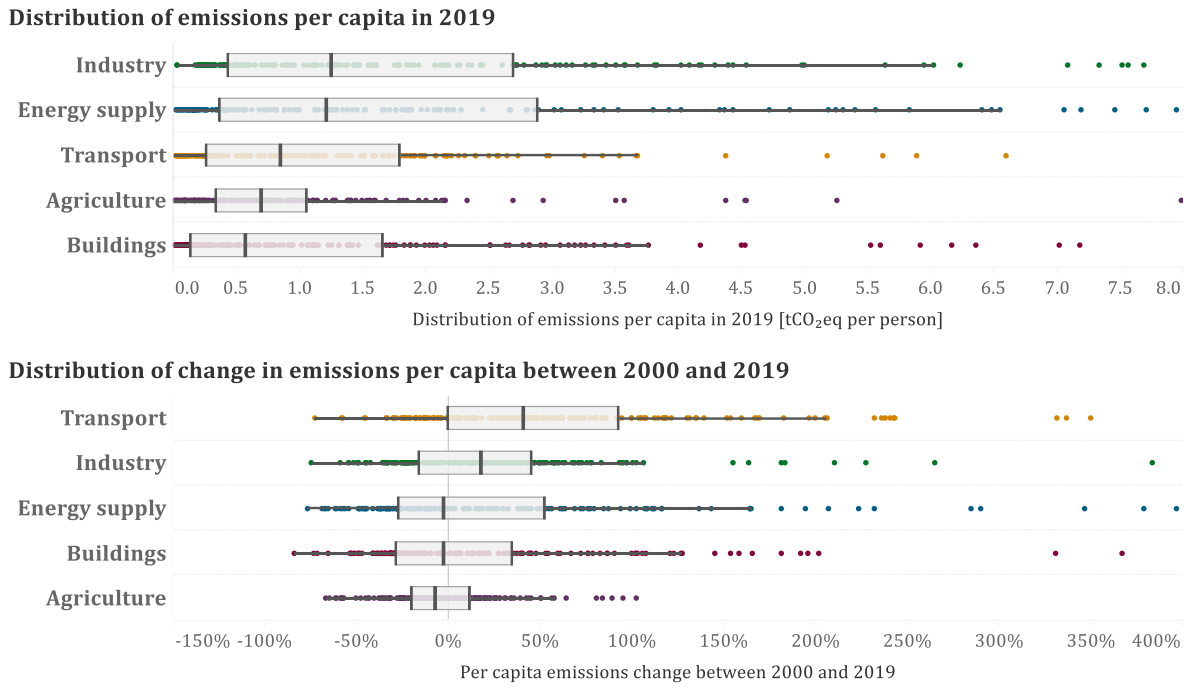

Figure 2: Distribution of per capita emissions per sector. Each dot represents one country, and the boxes cover the interquartile range (25th to 75th percentiles). The line in the centre of the box indicates the median, or central, country in the distribution. Whiskers cover 1.5 times the interquartile range. Some outliers are excluded from the plot for visualisation purposes but here this exclusion does not affect interquartile or median calculations. Source: Own calculations based on Minx et al. (2021)

For each sector, there are countries that managed to reduce GHG emissions per capita between 2000 and 2019. Reasons for these declines depend on country-specific circumstances. However, findings from countries that achieved sustainable emission reductions should be used to help other countries follow suit.

In several subsectors, such as electricity and heat production or managed soils and pasture, a decline in emissions per capita can be observed in the past five years (see Chapter 3). However, the observed development of total economy-wide emissions is not in line with the temperature goal of the Paris Agreement (Figure 1). To have a chance of limiting the temperature increase to 1.5°C, deep and sustained reductions in global greenhouse gas emissions are urgently needed.

In some sectors, such as buildings and agriculture, most countries have per capita emissions below 2000 levels. This is encouraging but to substantively decrease emissions in these sectors, profound changes are needed, which go beyond an increase in efficiency. In the buildings sector, such changes include the replacement of fossil-fuel based heating systems. In the agriculture sector, these include a transition towards diets based on reduced amounts of animal-based products in those countries where meat and dairy consumption is currently high.

In other sectors, such as industry and transport, a rapid change in direction is urgently needed. Most countries have per capita emissions above 2000 levels and emissions per capita in subsectors are still increasing. However, some countries show that such a change in direction is possible. Both in the industry and transport sectors, fossil fuels can be replaced by electricity as an energy source, provided that electricity can be supplied from renewable energy sources.

Current distributions of sectoral emissions per capita show a substantial spread of emissions per capita across countries. This highlights the importance of recognising differences in current circumstances and mitigation potential between countries.

Based on our findings, we recommend that the Global Stocktake:

- Applies the performance distribution approach to highlight rates of change of distinct indicators in line with what is required to meet the goals of the Paris Agreement
- Proposes that countries benchmark their efforts using these performance distributions to instigate a “race to the top” without naming and shaming individual countries
- Calls for the formulation of sector-specific visions that clarify the expectations for different sectors, enable the comparison of sectoral performance distributions to these benchmarks, and enable clearer sectoral progress evaluation and policymaking
- Sets the agenda for additional coalitions to address laggard sectors in addition to the formal ambition raising process of the Paris Agreement

In this submission, we present and analyse the performance distributions of historical emissions. This document is adapted from Nascimento et al. (2023). More data will be available in our forthcoming website globalstocktakedata.org, where the users can explore greenhouse gas emissions and energy data for themselves.

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1 Introduction

In the context of the Paris Agreement, countries agreed to the global goal of limiting the end-of-century global warming increase to well below 2°C and pursue 1.5°C (UNFCCC, 2015). The IPCC has shown that meeting these climate-change mitigation goals implies peaking and declining global GHG emissions by 2025 at the latest (IPCC, 2022). However, several studies assess global or sectoral greenhouse gas emissions to find that emissions have not yet peaked (Friedlingstein *et al.*, 2021; Lamb *et al.*, 2021). Others show that they are also unlikely to peak within the coming decade under currently adopted policies (UNEP, 2022). These studies show that progress to date remains insufficient to minimise the worst impacts of climate change.

Countries prepare and submit Nationally Determined Contributions (NDCs), which communicate their contributions to the goals of the Paris Agreement. These documents shall be updated at the latest every five years to reflect countries' highest possible ambition (UNFCCC, 2015). This 'pledge and review' cycle is designed to connect national efforts with the internationally agreed global goals to mitigate climate change and ensure their implementation.

Every five years, the Global Stocktake (GST) analyses global progress and informs 'Parties in updating and enhancing […] their actions and support […] as well as enhancing international cooperation' (para. 3, Art. 14, UNFCCC, 2015b). The Paris Agreement stipulates that the GST shall assess the collective progress towards achieving its long-term goals (UNFCCC, 2015). The first GST, taking place in 2021-2023, must also provide clear and actionable information to support Parties to the Paris Agreement (UNFCCC, 2022a). The information collected during the GST will inform NDC updates and consequently countries' measures to implement them.

Global analyses based on aggregated total or sectoral GHG emissions, hereafter just emissions, are largely influenced by major emitting countries and may hide trends of many individual countries. To complement these global studies, we analyse recent emission trends using performance distributions (Jeffery and Nascimento, 2022). Visualising country progress as distributions fulfils the GST's criteria of assessing collective progress while communicating that not all countries are the same. In the context of the GST, performance distribution analyses enable peer pressure among Parties and public scrutiny, which contribute to the enhancing ambition function of the GST process (Jeffery *et al.*, 2021). These distributions:

- Can be used to highlight how fast things can go in the right direction
- Can show how disparate progress between countries can be

This report intends to contribute to the ongoing GST process. It presents key sectoral developments without highlighting individual countries. In our website, users can select countries, which will then be added to the distribution for comparison. Users can also explore additional sub-sectors and datasets, including energy-related indicators as well as emissions, and compare information across different time periods.

For more information, please visit globalstocktakedata.org.

2 Methods

2.1 Performance distributions

A performance distribution is a histogram that groups countries based on how they fare on a specific indicator, such as sectoral GHG emissions per capita (Figure 3). These plots count countries within a certain interval and show which intervals contain more countries than others (Jeffery *et al.*, 2021). They also indicate how the indicator is spread across countries, which supports comparisons and assessing change over time. Additionally:

- Performance distributions are aligned with the GST mandate to assess **collective progress without singling out** individual countries
- They support national-level discussions, since interested actors can locate their country and **benchmark progress** against others
- They assess whether countries move together, or whether a few economies substantially affect global trends

Here, we focused on the progress of sectoral GHG emissions per capita. We use emissions per capita because it allows for easier comparison between countries, although we note the relevance of substantial differences in absolute emissions for the interpretation of the results. Evaluating emissions using this approach complements analyses based on aggregated emissions values and supports assessing progress towards decarbonisation. Performance distributions can also be used to analyse many other indicators, such as renewable energy capacity additions or number of electric vehicles sold, but this report focusses on GHG emissions.

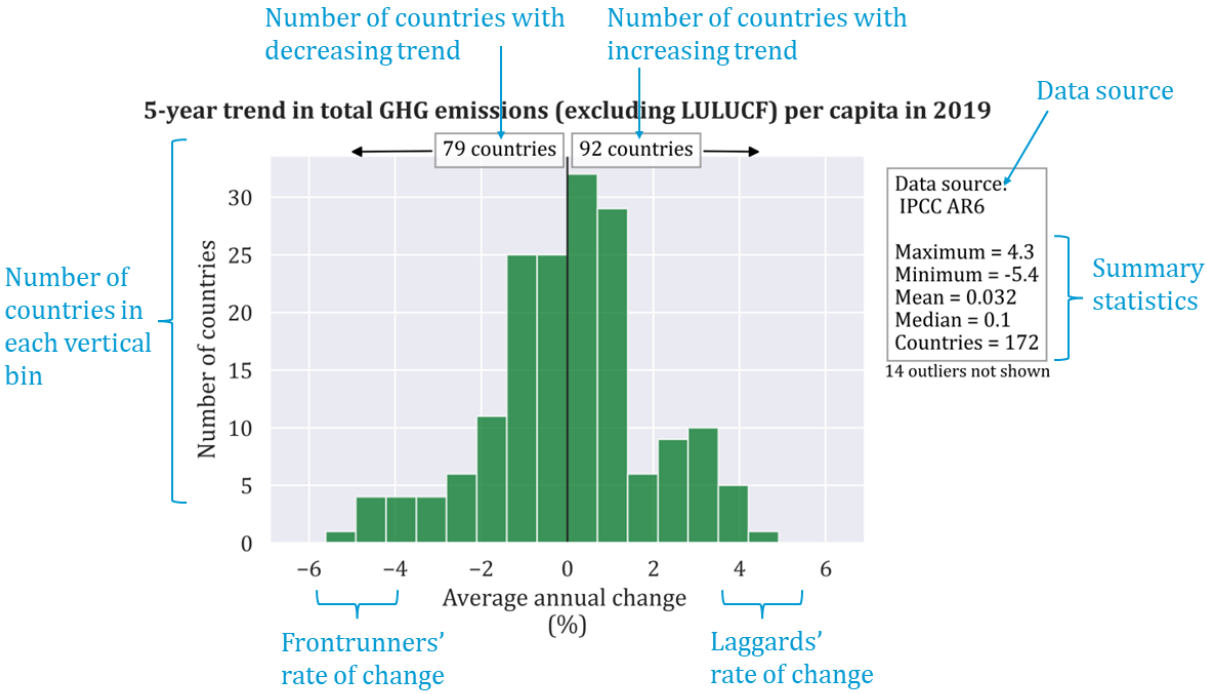

Figure 3: Example of performance distribution displaying the five-year trend of total emissions (excluding land use, land-use change and forestry) in 2019. Source: Own preparation based on data from Minx et al. (2021).

The analysis of per capita emissions shows whether historically they still increased across all sectors and countries, and which rates of change are more prevalent. In our analysis we assess the percent increase or decrease in emissions in all countries for which data is available. The analysis doesn't

distinguish between the absolute emissions in the country, which means that one country may have low and growing emissions, but still lower absolute emissions per capita than a country with high but decreasing per capita emissions. These differences are reflected in the first distribution presented in each of our sectoral analyses, but we note that the starting point of individual countries, and their responsibility for climate change can be very different. Examining trends in per capita emissions in a distribution rather aims to identify what has been feasible in terms of rates of reductions, and to assess how similar, or different, countries are in terms of current direction of travel.

Per capita emissions trends are therefore not the same as absolute emissions trends in a country. Some trends in per capita emissions can also be explained by factors such as:

- Emissions may be influenced by changes in activity, not emission intensity. For example, countries might change their economies' reliance from heavy industries to services, which are less emissions intensive; or
- Rapid increases in population with a delayed effect on sectors may result in short-term reductions in emissions per capita because lifestyle-related emission intensity tends to increase with age; or
- Fluctuations in countries with extremely low emissions per capita in some subsectors may influence the tails of distributions, since emission change rates may be substantial even though absolute values increase marginally

Although the underlying mechanisms explaining these trends cannot be uncovered by this approach, performance distributions add nuance to GHG emission analyses. They bridge global and national insights without naming and shaming countries. They can be coupled with country groupings to assess whether distinct policy constraints, income groups, or regions are associated with higher decline rates. Then, these groups can be further analysed to identify good practice examples to be replicated across countries. Such an approach would also shed light into the causal mechanisms while respecting the collective assessment of progress. Performance distributions can show the extent to which countries differ and highlighting these differences improves the understanding of global climate change mitigation progress.

2.2 Greenhouse gas emissions data and sectoral scope

In this report, we used per capita emissions, unless stated otherwise. We analysed performance distributions of three key emissions per capita metrics: the increase since 2000, the five-year trend in key subsectors and the most recent distribution.

The latest year of emissions analysed is 2019, we excluded 2020 and 2021 data due to the short-term change in trends induced by the COVID-19 pandemic. Our figures also exclude outliers, that are most often related to countries that have very low absolute emissions values. In these cases, even small increases in absolute emissions result in substantive growth rates. The total number of countries in each distribution may also vary because some countries did not have emissions in specific sectors and/or subsectors.

We used the historical emission dataset prepared in the context of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) through 2019 (Minx *et al.*, 2021; Dhakal *et al.*, 2022). We also attributed indirect emissions associated with electricity and heat production to energy-use sectors, as described in Lamb et. al (2021). This dataset presents sufficient sectoral detail to analyse emission trends in sectors and subsectors. The dataset covers 186 individual countries, with data until 2019 available for all countries but Eritrea. Population data for calculating per capita emissions is taken from the UN Population Division (UN DESA, 2022).

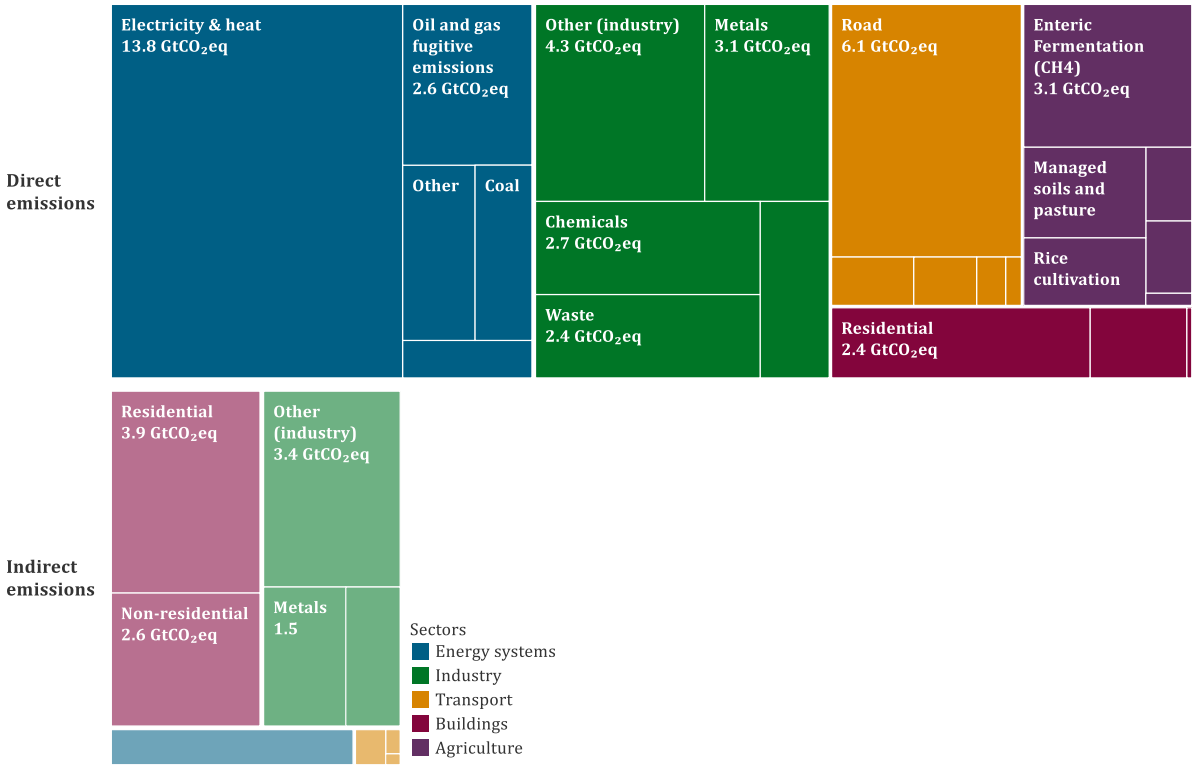

Figure 4: Distribution of absolute emissions per sector (excl. LULUCF) in 2019. Direct emissions include all emissions allocated directly to these sectors and indirect emissions refer to emissions from electricity and heat that is consumed in industry, buildings and transport. The boxes without text refer to subsectors that represent a small share of total emissions. The full list of subsectors is presented in the appendix, which also includes 2019 emissions totals for these subsectors. Source: Own aggregation based on Minx et at. (2021)

In our analysis, we focused on sectoral progress, specifically in energy supply, industry, transport, buildings, and agriculture sectors (Figure 4). We excluded emissions associated with land use, land-use change and forestry (LULUCF), international aviation and international shipping. We excluded LULUCF emissions due to high year-to-year fluctuations, which affect calculation of national trends. We excluded international transport (aviation and shipping) since it is not allocated to specific countries.

Our analysis of energy supply distributions includes all emissions, such as those related to energy use in other sectors (i.e., indirect emissions from buildings, transport and industry are included). Additionally, our analysis of energy end-use sectors includes indirect emissions (see also appendix). Indirect emissions are therefore included both in the energy supply and energy end-use sectoral analyses to allow for a better understanding of emissions drivers. We ensure that there is no double-counting when aggregating emissions to cross-sector country totals.

All emissions presented in our report are reported in terms of CO_2-equivalents based on the global warming potentials (GWP) of the IPCC Fifth Assessment Report (IPCC, 2014).

3 Performance distributions of sectoral emissions

3.1 Cross-sectoral analysis

Global absolute GHG emissions increased substantially in the past two decades, but this increase varies across sectors. Absolute emissions increased faster in the industry and energy supply sectors (Figure 5 – left). Regions with fast growing populations and/or energy demand drive most of this increase (Lamb *et al.*, 2021). However, per capita global emissions also increased; the average emission intensity associated with the lifestyle of each person is higher than it used to be.

Emissions per capita increased in all sectors, except agriculture (Figure 5 - right). This suggests that the growth observed in total agriculture emissions is driven by population growth and that agricultural practices have become less emissions intensive since 2000. The industry sector shows the highest per capita emission growth between 2000 and 2019, followed by energy supply and transport.

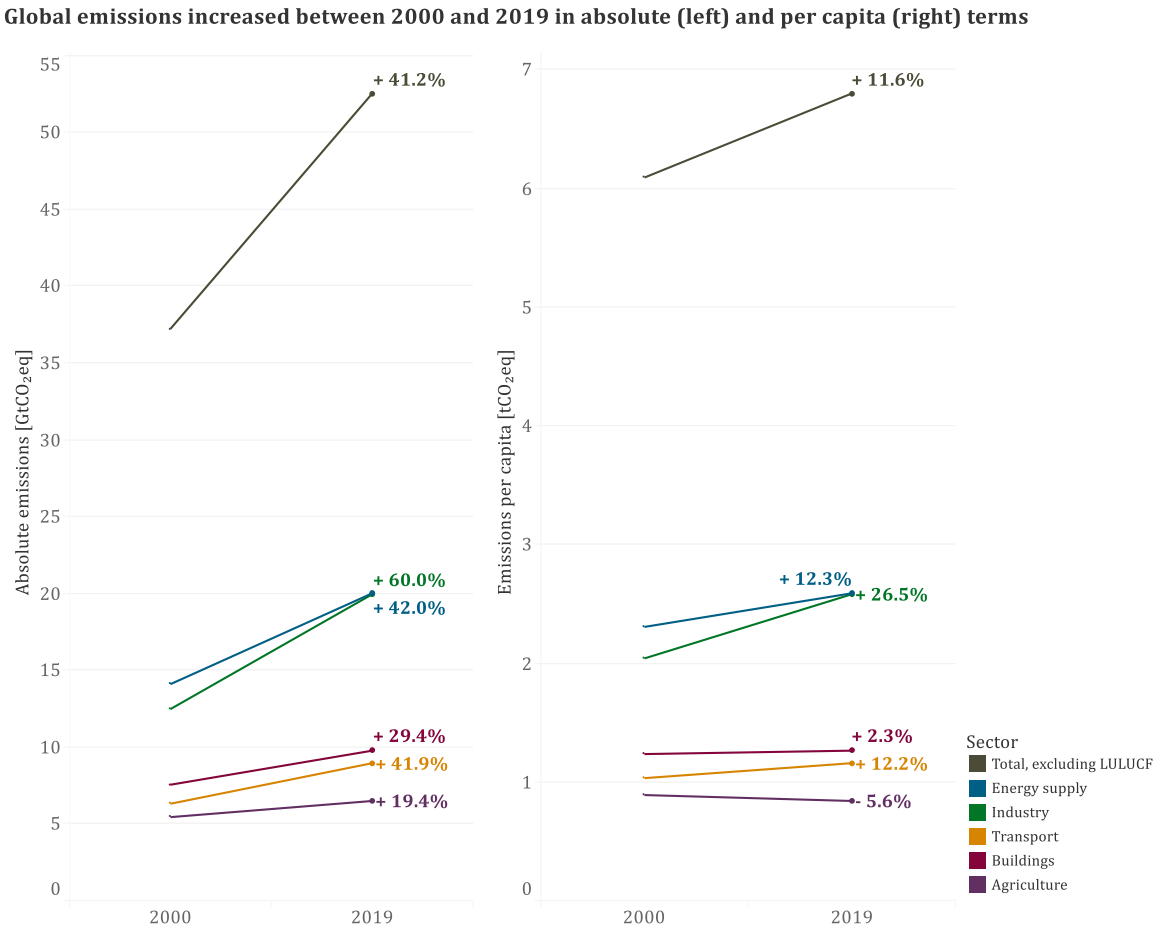

Figure 5: Global emissions excluding LULUCF in 2000 and 2019. Percentages are based on the change rate calculated between 2000 and 2019. Emissions from energy supply also include indirect emissions that are allocated to energy end-use sectors. However, the total does not double count these indirect emissions. Please note the different axis and units across charts. Source: Own calculations based on Minx et at. (2021)

Transport- and industry-related emissions per capita increased in over half of the countries (positive median increase in Figure 6 – bottom). This suggests that the global trend is driven by an increase of emissions across several countries. In the transport sector, only one-quarter of the countries have per capita emissions below 2000 levels (lower quartile around 0% in Figure 6 – bottom), in contrast to slightly

over one-third in industry. However, in the energy supply sector, we observe that most countries have 2019 per capita emissions below 2000 levels (median below 0% in Figure 6 – bottom). This suggests that the global increase in per capita emissions from energy supply is driven by fewer large emitters.

In addition to energy supply, over half of the countries have buildings- and agriculture-related per capita emissions below 2000 levels. The relatively low increase in the buildings sector's global emissions per capita and the decline in agricultural per capita emissions, as depicted in Figure 6, can partly be explained by the observation that over half of countries had decreasing per capita emissions in these sectors between 2000 and 2019. Approximately one-quarter of countries have per capita emissions over 30% below 2000 levels in the energy supply and buildings sectors. In agriculture, one-quarter of the countries have per capita emissions 20% below 2000 levels.

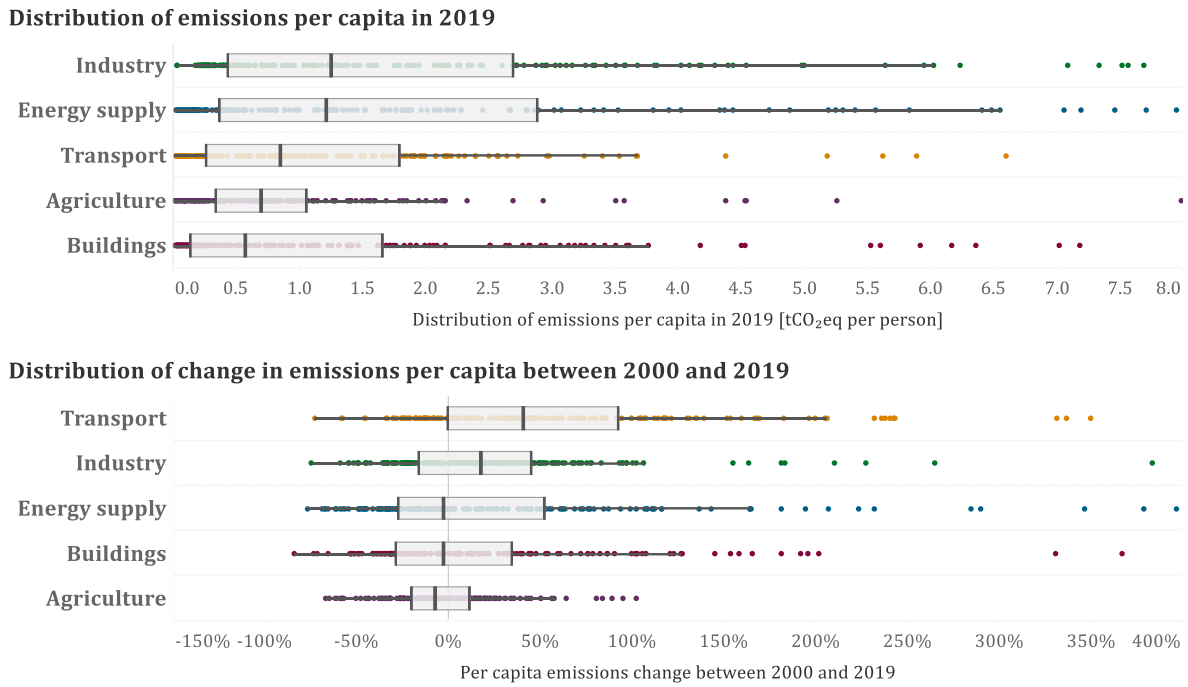

Figure 6: Distribution of per capita emissions per sector. Each dot represents one country and the boxes cover the interquartile range (25th to 75th percentiles), meaning that the box contains half of the countries for each sector. The line in the centre of the box indicates the median, or central, country in the distribution. Therefore, the area outside the box to the left contains one-quarter of the countries, namely those with lowest values, and the area to the right also contains one-quarter of the countries, this time those with the highest values. Whiskers cover 1.5 times the interquartile range. Some outliers are excluded from the plot for visualisation purposes but here this exclusion does not affect interquartile or median calculations. Source: Own calculations based on Minx et al. (2021)

Emissions per capita are also substantially spread across sectors (Figure 6 – top). The median value across sectors reflects the share of total emissions attributable to that sector. For example, the energy supply sector is the largest emitter so its emissions per capita are also on average higher when compared to other sectors.

However, the distribution of emissions within the sector indicates that significant differences across countries persist. In all distributions low values are more prevalent than high values of emissions per capita. Over half of the countries have emissions below 1.5 tCO_2e per person in 2019 in all sectors. The difference between countries with lower and higher emissions per capita is more substantial in the buildings and energy supply sectors.

On the following pages, distributions for each of five sectors are described in more detail.

3.2 Energy supply

- Most countries had lower energy supply emissions per capita in 2019 than in 2000.
- The average (mean) country had 18% higher emissions per capita in 2019 than in 2000.
- In the past five years, fugitive emissions per capita declined in almost two-thirds of countries, while emissions related to electricity and heat production declined in only half.

Long-term change and current distribution of emissions per capita

The energy sector is the largest emitter and is alone responsible for approximately 35% of global emissions (Lamb *et al.*, 2021). Per capita emissions increased by 18% from 2000 to 2019 (across-country average). Although emissions are lower than 2000 levels in 96 countries, emissions per capita have more than doubled in several countries (Figure 7). Most countries had emissions per capita in the sector below 1 tCO_2eq in 2019. Thirteen countries (outliers not shown in the distribution) have emissions above 10 tCO_2eq per capita.

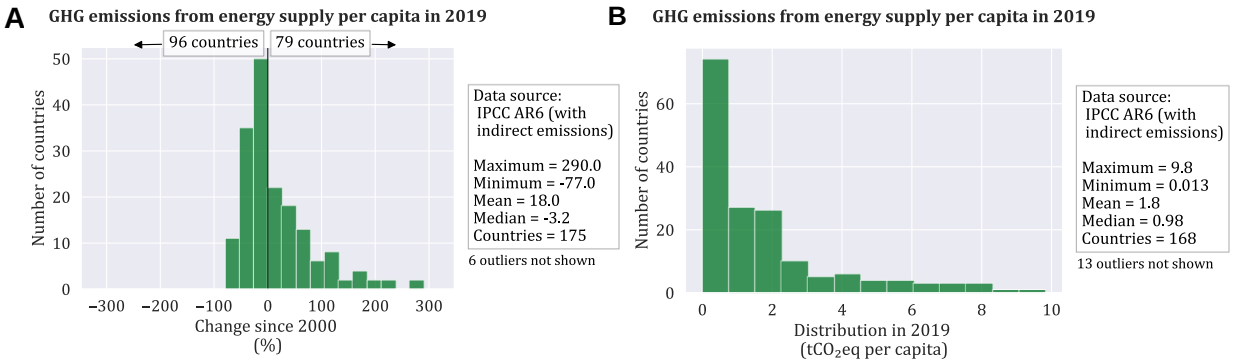

Figure 7 Distribution and change since 2000 in emissions per capita in the energy supply sector

Recent change in key subsectors

Two subsectors are responsible for 28% of global emissions. Electricity and heat production is responsible for 24% and oil and gas production for 4% (Lamb *et al.*, 2021). In the past five years, fugitive emissions from oil and gas production declined in most countries (Figure 8). However, uncertainties about these emissions range between half and double of the central estimate for the same year (Solazzo *et al.*, 2021). The range of national estimates is even larger. Emissions per capita from electricity and heat production declined in approximately half of the countries and over 20 countries show an average decline of above 5% per year in the past five years.

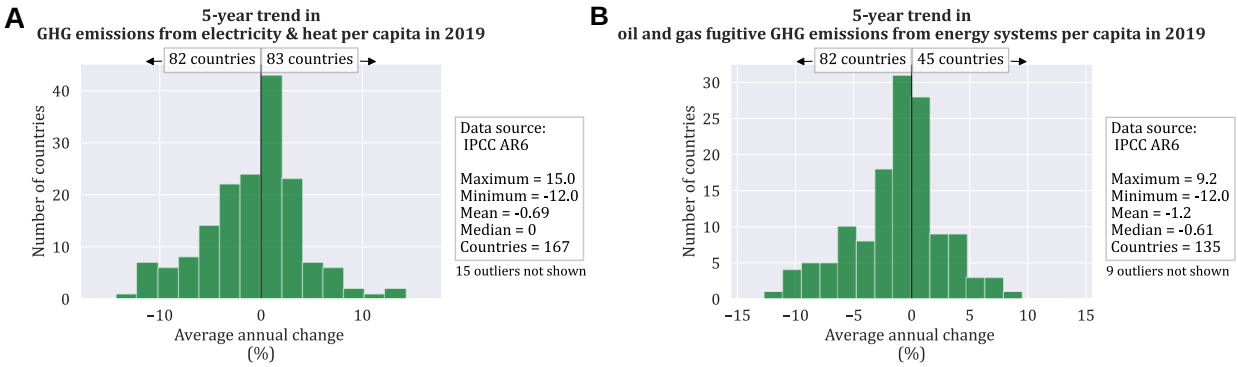

Figure 8 Distribution of recent trends of per capita emissions in key energy supply sub-sectors

3.3 Industry

- The average (mean) country increased emissions per capita by 20% between 2000 and 2019
- In 2019, almost two-thirds of the countries have emissions per capita above 2000 levels
- Emissions per capita have been trending down in the two most emission-intensive industrial sectors (metals and chemicals production)

Long-term change and current distribution of emissions per capita

The industry sector emits approximately one-quarter of global emissions (Lamb *et al.*, 2021). Per capita emissions increased 20% between 2000 and 2019 (across-country average). Emissions are higher than 2000 levels in almost three-quarters of the countries (Figure 9). Although several countries doubled their emissions per capita, many others halved them in the same period. This trend is influenced by shifts in economic activity in these countries. For example, countries that relocated heavy industries abroad may show reduced industrial emissions per capita.

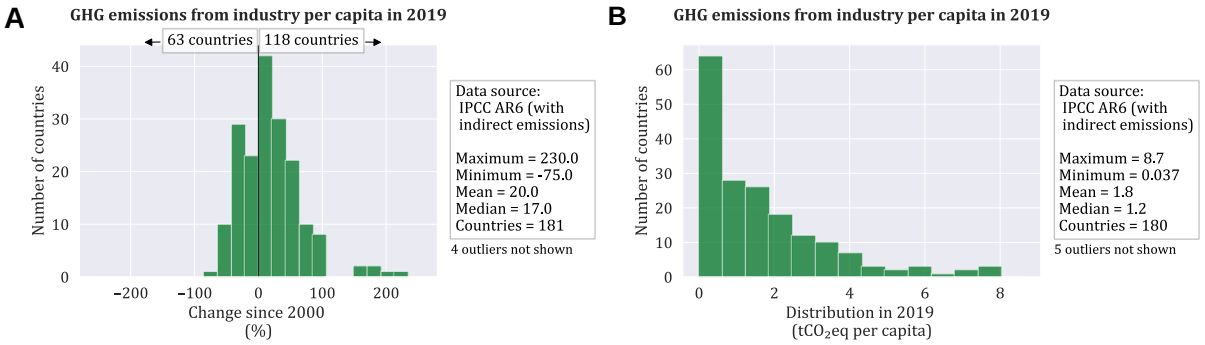

Figure 9 Distribution and change since 2000 in emissions per capita in the industry sector

Recent change in key subsectors

The industry sectors represents almost 30% of global emissions, incl. indirect emissions (Lamb *et al.*, 2021). Steel (and other metals) and chemicals production are the largest contributors in the sector. The average country declined emissions from the metals industry by approximately 1% per year in the past five years (Figure 10). However, several countries reduced emissions by over 10% per year in the same period. A similar trend is observed in the chemicals sector. Since 2014, emissions per capita in chemical production declined in most countries and some show average decline close to 5% per year in the past five years.

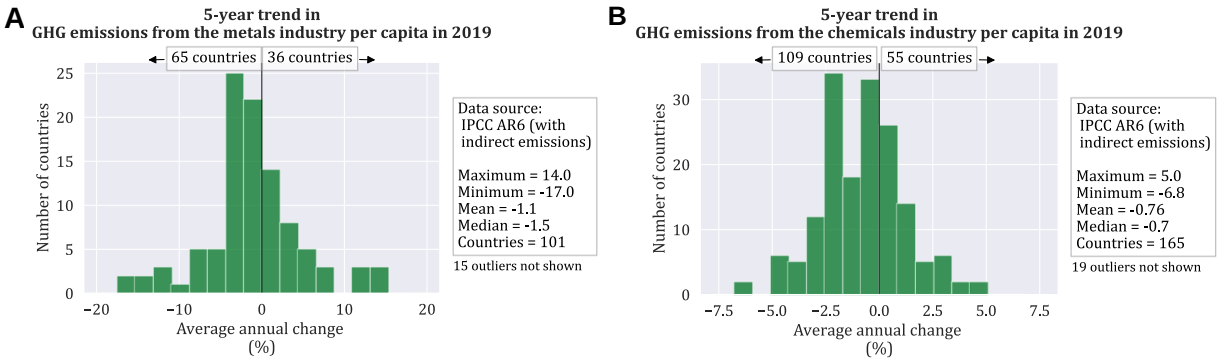

Figure 10 Distribution of recent trends of per capita emissions in key industry sub-sectors

3.4 Transport

- Per capita transport emissions increased from 2000 to 2019 in the vast majority of countries
- The average country's emissions per capita increased 54% between 2000 and 2019
- Road transport contributes the highest share of emissions, which increased in most countries

Long-term change and current distribution of emissions per capita

Transport contributes almost 15% of global emissions (Lamb *et al.*, 2021). Per capita emissions show the highest growth from all sectors analysed – the average country growth is approximately 50% between 2000 and 2019 (Figure 11). Emissions are higher than 2000 levels in three-quarters of the countries and have more than tripled in several countries. Most countries have emissions per capita in the sector below 0.9 tCO_2eq per capita in 2019. Indirect emissions contribute to a small share of emissions in the sector (Lamb *et al.*, 2021).

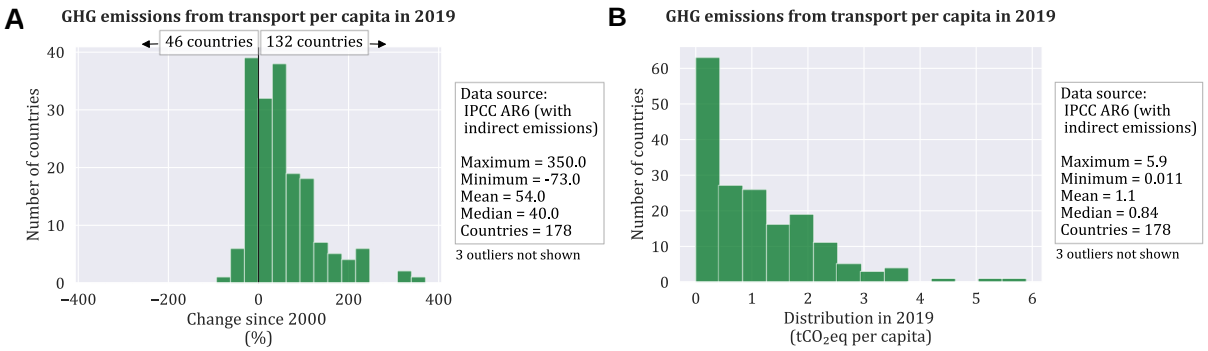

Figure 11 Distribution and change since 2000 in emissions per capita in the transport sector

Recent change in key subsectors

Road transport is responsible for most of national transport-related emissions, followed by domestic aviation (Lamb *et al.*, 2021). In the past five years, emissions per capita increased 1.2% per year in road transport and 0.9% in domestic aviation (across-country averages). In a few cases, road transport emissions per capita increased over 10% per year (Figure 12). National average domestic aviation emissions per capita are very low (mean 0.08 tCO_2eq per person compared to 5.61 tCO_2eq per person for road transport), which affects calculation of growth rates. Therefore, substantial decline in short-term emissions in this subsector must be considered with caution.

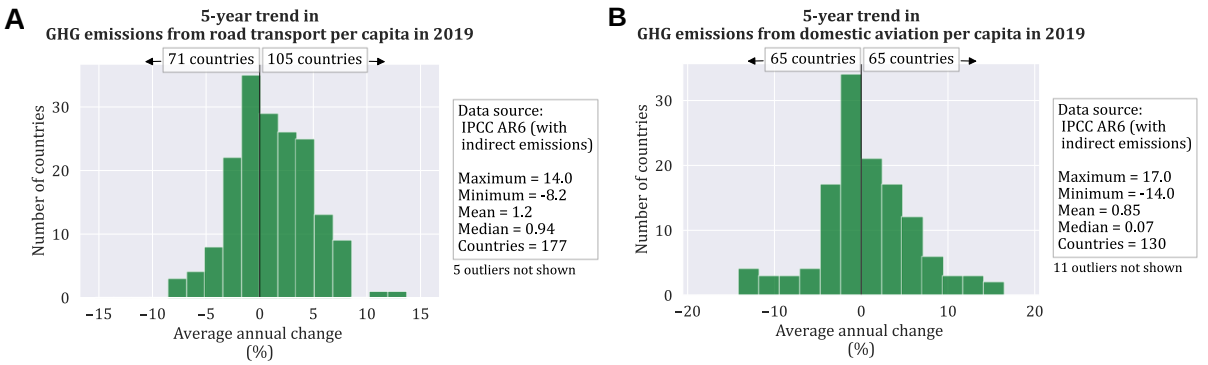

Figure 12 Distribution of recent trends of per capita emissions in key transport sub-sectors

3.5 Buildings

- The average (mean) country increased emissions per capita by 11% between 2000 and 2019
- The production of electricity and heat for buildings is responsible for most emissions in the sector but declined in 70 out of 120 countries analysed in the past years
- Direct emissions of residential buildings increased in most countries since 2014

Long-term change and current distribution of emissions per capita

The buildings sector was responsible for 5% of global direct emissions in 2019. However, when we consider indirect emissions from electricity and heat production, this share increases to 15% (Lamb *et al.*, 2021). Energy needs for heating and cooling buildings are a major emissions driver and vary strongly between countries depending on the local climate. Although emissions per capita are below 2000 levels in most countries (negative median), the average country increased emissions since 2000 by 11% (Figure 13).

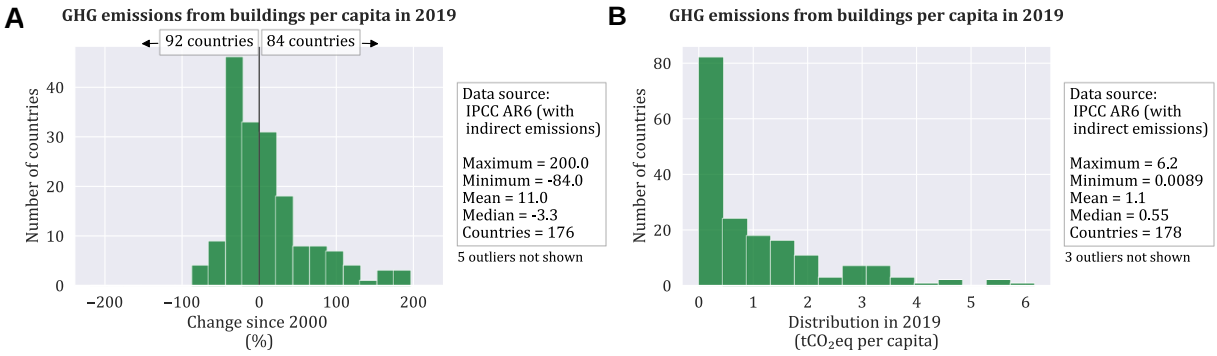

Figure 13 Distribution and change since 2000 in emissions per capita in the buildings sector

Recent change in key subsectors

Indirect emissions, from using electricity for lighting and appliances for example, have driven the increase of buildings emissions over the last two decades (Lamb *et al.*, 2021). However, in per capita terms, indirect emissions decreased 1% per year (across-country average) in the past years. Direct emissions, including fossil-fuel for heating, from residential buildings increased in most countries analysed, but some countries' emissions declined more than 5% per year in the past five years (Figure 14).

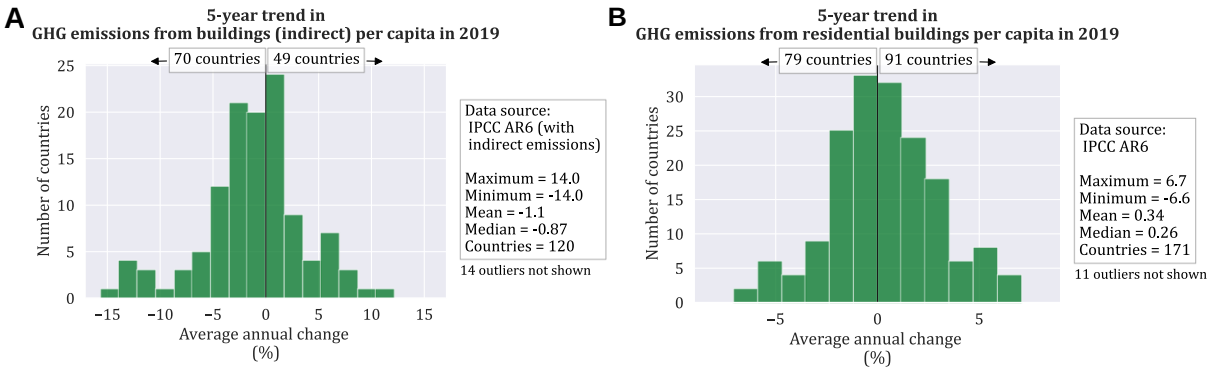

Figure 14 Distribution of recent trends of per capita emissions in key buildings sub-sectors

3.6 Agriculture

- In 2019, per capita emissions were below 2000 levels in most countries
- The average country's emissions per capita declined by 4% between 2000 and 2019
- Recent trends show a mean decline of almost 1% per year in key subsectors

Long-term change and current distribution of emissions per capita

Here, we focus on emissions from agriculture and exclude land-use-related carbon dioxide emissions and removals because their high year-to-year fluctuations substantially affect trend analyses. Agriculture contributes to approximately 10% of global emissions (Lamb *et al.*, 2021). Per capita emissions are below 2000 levels in most countries (Figure 15). On average, emissions are below 2000 by almost 4% (across-country average). Most countries have emissions in the sector below 0.7 tCO_2eq per capita in 2019.

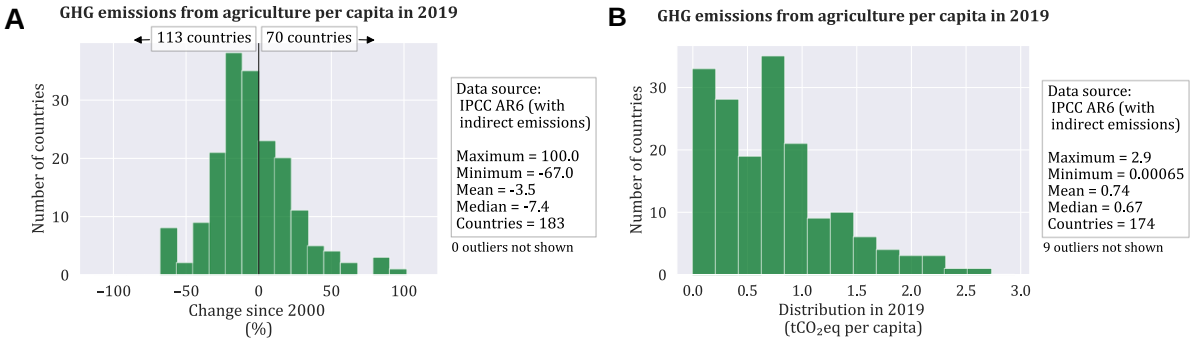

Figure 15 Distribution and change since 2000 in emissions per capita in the agriculture sector

Recent change in key subsectors

The highest share of agriculture emissions is caused by enteric fermentation, which are associated with husbandry of ruminant animals such as cattle, followed by managed soils and pasture (Lamb *et al.*, 2021). In both sub-sectors, emissions decreased in more countries than they increased. In the past five years, emissions per capita from enteric fermentation decreased 0.7% per year and emissions from managed soils and pasture decreased by 0.5% (across-country averages) (Figure 16).

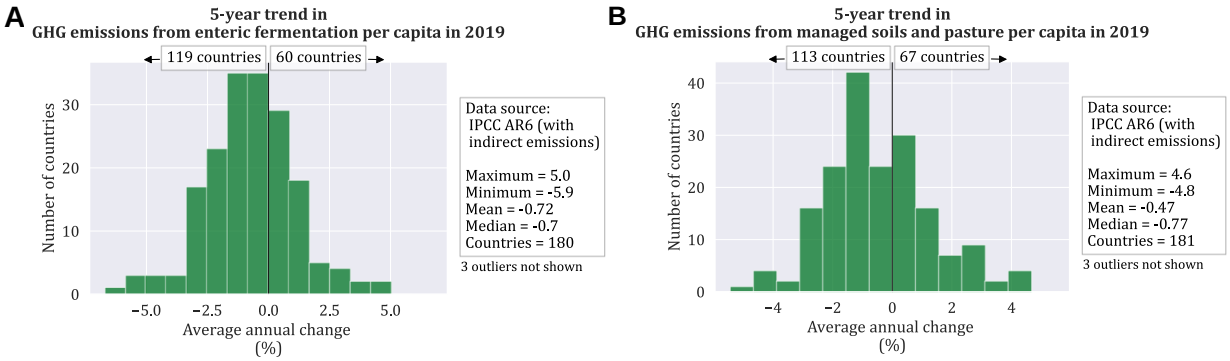

Figure 16 Distribution of recent trends of per capita emissions in key agriculture sub-sectors

4 Conclusions

In our analysis, we used the performance distribution approach to analyse sectoral historical emission per capita trends. We evaluated how per capita emissions have changed since 2000, how they have changed in key sectors in the past five years, and their current distribution. We used a well-established emissions dataset that allowed allocation of indirect emissions related to electricity and heat consumption to their end-use sectors.

We find that in 2019 more than half of the countries had emissions per capita below 2000 levels in energy supply, buildings, and agriculture. Global agricultural emissions per capita decreased since 2000, but emissions per capita from buildings and energy supply increased since then. This suggests that the increase in emissions per capita in energy supply and buildings is driven by a few large emitters. Absolute and per capita emissions have also increased since 2000 in transport and industry. In transport, per capita emissions increased in the largest share of countries (~75%), indicating that transport is a laggard in mitigating emissions among the sectors analysed.

Similar trends are observed in key subsectors in recent years. Emissions per capita have declined in the past five years in over half of the countries in almost all sub-sectors analysed. We also observed rates of decline above 10% per year in some industry and energy supply subsectors. Comparing recent trends in sub-sectors also shows the transport sector as a laggard. Emissions per capita associated with road transport increased in almost two-thirds of the countries.

More generally we find that:

- In all sectors, emissions per capita in several countries decreased between 2000 and 2019. Reasons for these declines depend on country-specific circumstances. But findings from countries that achieved sustainable emission reductions can provide lessons for others.
- In several subsectors, countries show a recent decline in emissions per capita. However, the development of total emissions observed in recent years is not in line with the temperature goal of the Paris Agreement. As pointed out by the Conference of the Parties (COP) at its 27th session (UNFCCC, 2022b), 'limiting global warming to 1.5 °C requires rapid, deep and sustained reductions in global greenhouse gas emissions of 43 per cent by 2030 relative to the 2019 level'.
- In some sectors, such as buildings and agriculture, most countries have per capita emissions below 2000 levels. This is encouraging but in order to substantively decrease emissions in these sectors, profound changes are needed, which go beyond an increase in efficiency. In the buildings sector, such changes include the replacement of fossil-fuel based heating systems. In the agriculture sector, these include a transition toward diets based on reduced amounts of animal-based products in those countries where meat and dairy consumption is currently high.
- In other sectors, such as industry and transport, a rapid change in direction is needed since most countries have per capita emissions above 2000 levels and emissions per capita in subsectors are still increasing. However, some countries show that such a change in direction is possible. Both in the industry and transport sectors, fossil fuels can be replaced by electricity as an energy source, provided that electricity can be supplied from renewable energy sources.
- Current distributions of sectoral emissions per capita show a substantial spread of emissions per capita across countries. This highlights the importance of recognising differences in current circumstances and mitigation potential between countries.

Performance distributions help to identify, for example, whether the observed increase in global emissions per capita since 2000 is driven by a few large emitters or whether countries have moved together. Although progress on average remains slow, several countries show promising rates of decline in sectoral emissions. Understanding the mechanisms underlying these trends would require further analysis that examines the technical, political, and economic factors in these countries. Additional analysis is also needed to identify who is capable and responsible for implementing action. Performance

distributions are helpful in showing that several good practice cases do exist. Identifying and replicating these good practice examples is key to improving collective efforts towards the goals of the Paris Agreement.

As of spring 2023, it will be possible to explore similar information for additional sub-sectors and datasets on the website – globalstocktakedata.org.

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Appendix

Our analysis used the sector categorisation of Minx et. al (2021) (Table 1). The attribution of indirect emissions to energy end-use sectors follows Lamb et. al (2021). This attribution is based on CO_2 emission data from the International Energy Agency from 1990 onwards (IEA, 2021).

Table 1 Sector definition and inclusion of indirect emissions

Sector	Subsector	Includes indirect emissions	2019 emissions (Gt CO_2e)
Agriculture	Biomass burning (CH4, N2O)	No	0.07
Agriculture	Enteric Fermentation (CH4)	No	3.07
Agriculture	Managed soils and pasture (CO2, N2O)	No	1.42
Agriculture	Manure management (N2O, CH4)	No	0.44
Agriculture	Rice cultivation (CH4)	No	1.06
Agriculture	Synthetic fertilizer application (N2O)	No	043
Buildings	Non-CO2 (all buildings)	No	0.04
Buildings	Non-residential	Yes	3.45
Buildings	Residential	Yes	6.26
Energy systems	Coal mining fugitive emissions	No	1.29
Energy systems	Electricity & heat	No – emissions allocated to energy end-use sectors	13.84
Energy systems	Oil and gas fugitive emissions	No	2.64
Energy systems	Other (energy systems)	Yes	2.77
Energy systems	Petroleum refining	No	0.63
Industry	Cement	No	1.55
Industry	Chemicals	Yes	3.67
Industry	Metals	Yes	4.59
Industry	Other (industry)	Yes	7.71
Industry	Waste	No	2.4
Transport	Domestic Aviation	No	0.39
Transport	Inland Shipping	No	0.18
Transport	Other (transport)	Yes	0.53
Transport	Rail	Yes	0.25
Transport	Road	Yes	6.18

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