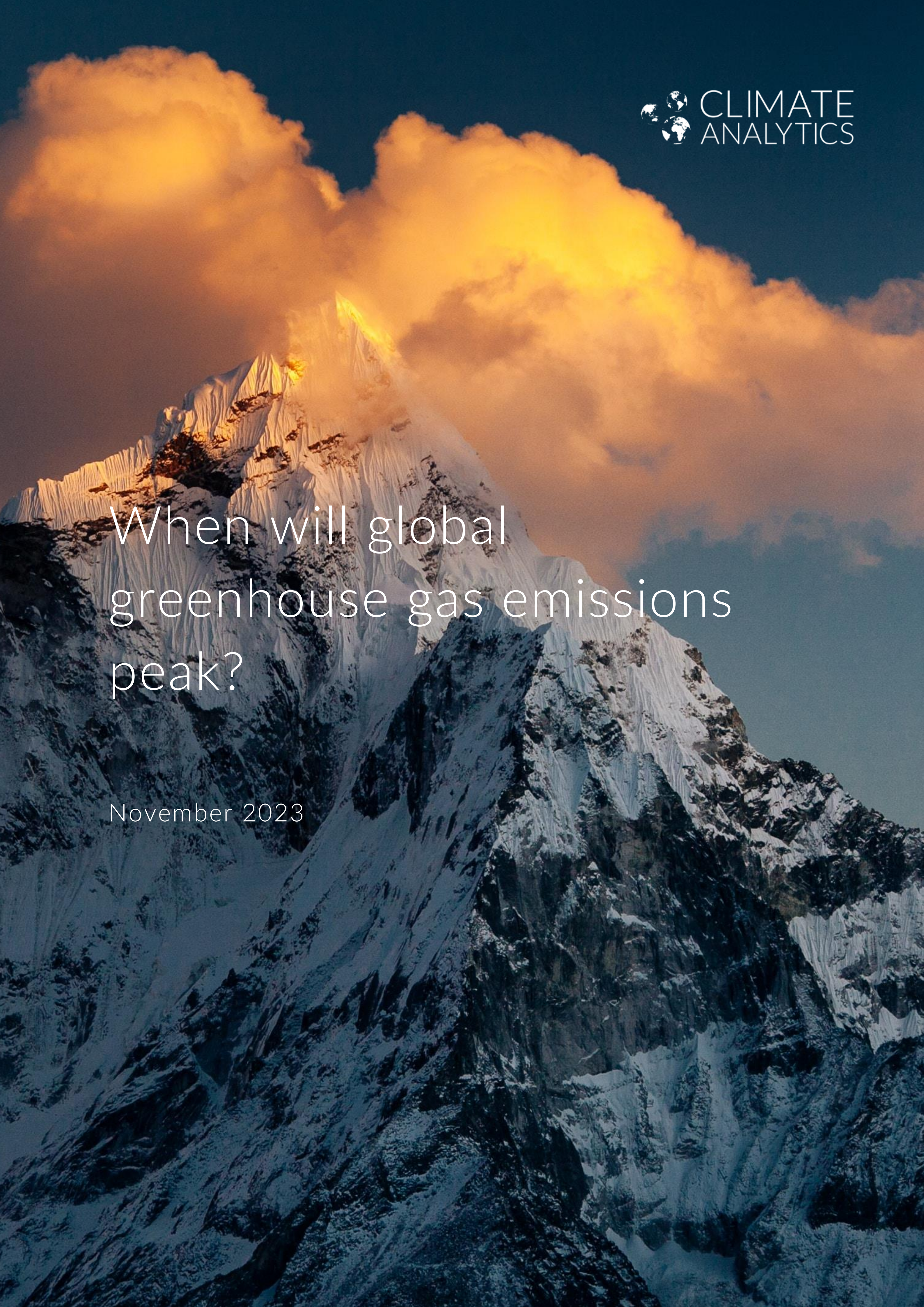

When will global greenhouse gas emissions peak?

November 2023

AUTHORS

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ABOUT CLIMATE ANALYTICS

Climate Analytics is a global climate science and policy institute. Our mission is to deliver cutting-edge science, analysis and support to accelerate climate action and keep warming below 1.5°C.

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Summary

Reaching peak global greenhouse gas emissions – the point at which emissions stop growing and start falling – will be a crucial inflection point for the world. Instead of speeding in the wrong direction, we could finally say we're making the turn towards our collective climate goals.

The IPCC says peaking before 2025 is a critical step to keep the 1.5°C limit within reach. With emissions set to rise in 2023, this leaves limited time to act. To assess if we can meet this milestone, we look at when global emissions might peak, as well as what we can do to get there in time.

We find there is a **70% chance that emissions start falling in 2024** if current clean technology growth trends continue and some progress is made to cut non-CO_2 emissions. This would make **2023 the year of peak emissions – meeting the IPCC deadline**.

The continued explosive growth of wind and solar in particular would push fossil fuels out of the power sector, leading to **peak coal in 2023 and peak gas in 2024.** Meanwhile, continued growth in electric vehicles could lead to **peak oil in 2025.**

Our analysis looks at three scenarios. The first (baseline), combines the IEA's current policy projection – which shows global fossil CO_2 emissions peaking this year – with an assumption that other gases continue growing at current rates. In this scenario, global greenhouse gas emissions enter a long-term plateau, even if fossil CO_2 emissions peak.

Our second scenario (low effort) continues to use the IEA's projection for fossil CO_2 but assumes internationally agreed targets to reduce hydrofluorocarbons are met, and low-cost, no-regrets action is taken to cut other non-CO_2 emissions over the coming years. In this scenario, emissions peak in 2025, narrowly missing the IPCC's 'before' 2025 milestone.

Our third scenario, and focus of this report, (continued acceleration) looks at what happens if current growth trends in wind, solar and electric vehicles seen at the regional and national level are maintained – with country-level analyses conducted for China, the US, the EU, India and Brazil. It also assumes signatories to the Global Methane Pledge make adequate progress towards achieving the collective target.

This is the only scenario which meets the IPCC milestone, peaking in 2023 with a high confidence (70%) when accounting for year-to-year emissions fluctuations.

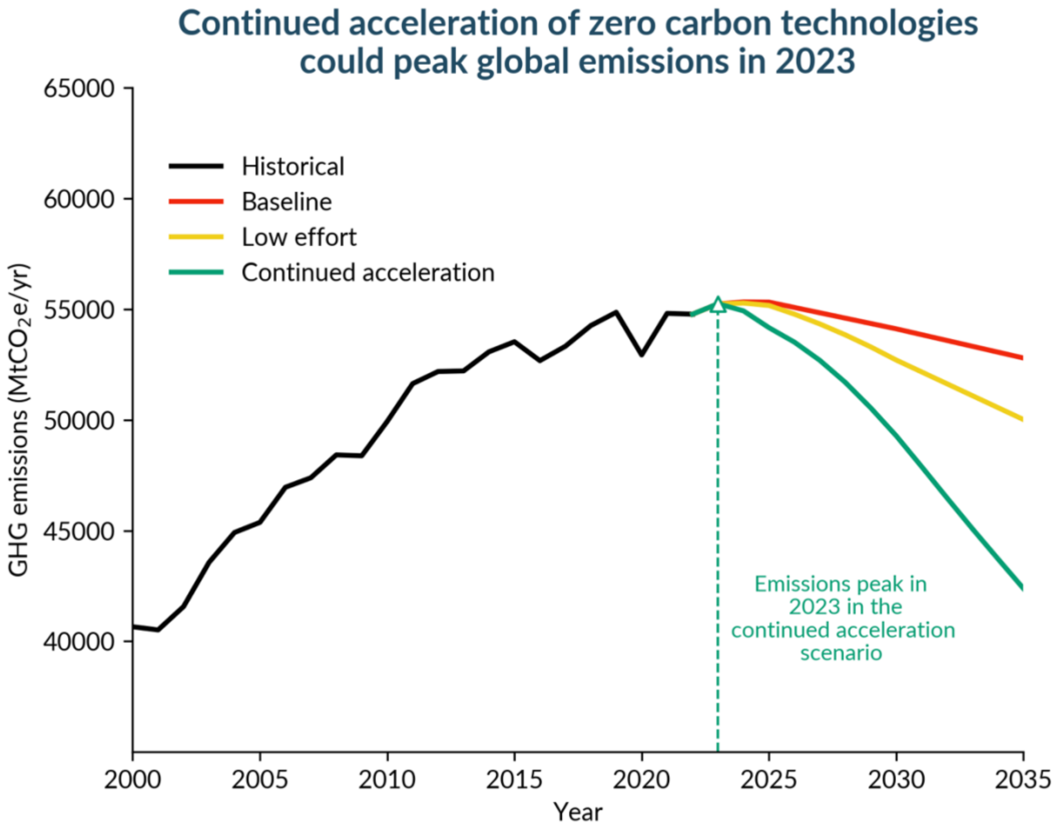

Figure ES1: Future greenhouse gas emissions in the three scenarios developed in this work.

IEA current policy projections tend to be conservative when compared to actual wind and solar growth data. To adjust for this, the continued acceleration scenario follows an S-curve which emulates the explosive growth of maturing technologies. This shows a faster decline in CO_2 emissions compared to the IEA's scenario and results in around 2.5 times more renewable capacity in 2030 than today.

In the continued acceleration scenario, the rapid scale up of zero-carbon technologies begins to outstrip growth in energy demand for the first time, causing fossil fuel demand to peak and start falling. With peak coal, oil and gas on the near horizon, any expansion of fossil fuel production represents a huge stranded asset risk and could slow the energy transition.

Our analysis focuses on four key actions governments can take over the next two years to peak in time. Getting behind the success of wind, solar and electric vehicles is the most powerful in terms of emissions savings, followed by concerted action on methane (Figure ES2). Other key actions, including the rapid rollout of heat pumps and energy efficiency improvements, were not assessed due to data availability but would bring emissions down even faster.

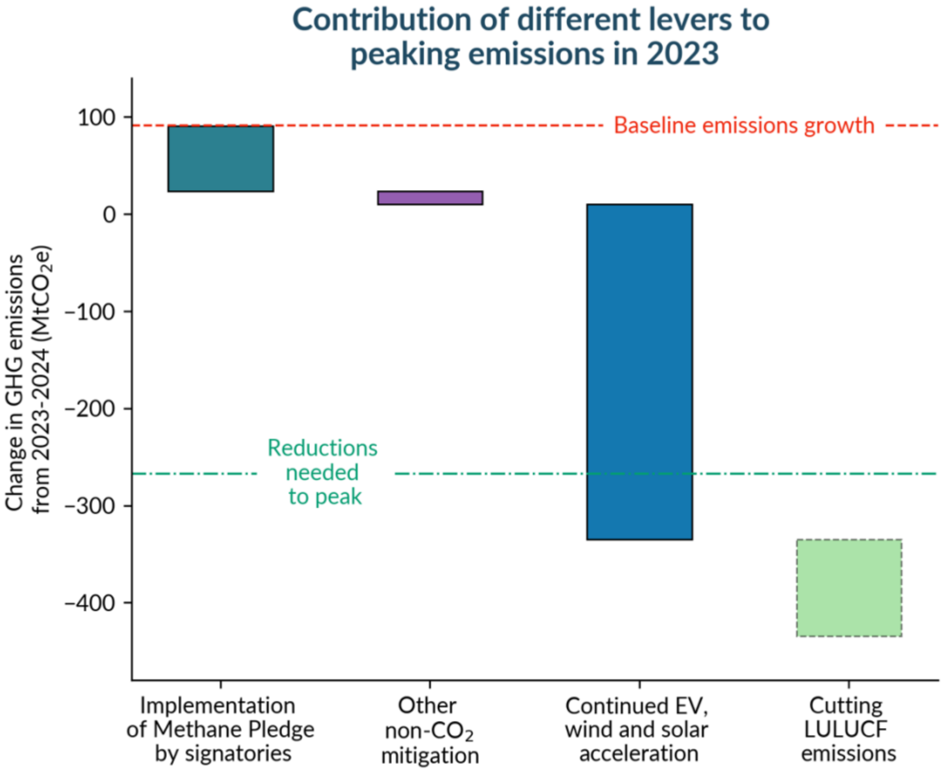

Figure ES2: Emissions savings in 2024 compared to 2023 in the continued acceleration scenario, plus LULUCF emissions savings (due to high uncertainties, we don't rely on cuts to LULUCF emissions in the scenarios).

Peaking emissions on its own is not enough to limit warming to 1.5°C. In the continued acceleration scenario, global emissions fall 10% by 2030 relative to 2019 levels – less than a quarter of the way towards the 43% cuts the IPCC says is needed to keep the Paris Agreement goal within reach. Although a key milestone, a global peak must be followed by a sharp and sustained fall in emissions over the following years.

By 2030, we will need to triple renewables, double energy efficiency, accelerate the electrification of energy demand sectors, halt deforestation, and slash methane emissions by over 30%. Global clean energy investments need to be ramped up 2.5-fold, with greatest increases happening in emerging economies. New fossil fuel production plans will need to be axed, with fossil fuel production falling around 40% over the decade on the road to a full, fast and fair fossil phase out.

At COP28, it is more important than ever that governments follow the science. A commitment to peaking global emissions before 2025, alongside the above actions urgently needed this decade, would show that governments are serious about keeping the 1.5°C limit in reach. The race to peak emissions is ours to lose, but it’s also a race we can – and must – win.

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Introduction

Global emissions are still rising. The more fuel we add to climate change each year, the faster we race towards dangerous tipping points, and the shorter our braking distance. This is why governments agreed in 2015 as part of the Paris Agreement to peak emissions 'as soon as possible' as a first key step towards meeting the long-term temperature goal.

The Intergovernmental Panel on Climate Change (IPCC) finds that peaking global greenhouse gas (GHG) emissions before 2025 at the latest and further reducing them by 43% by 2030 is the best route towards limiting warming to 1.5°C (IPCC 2022).

Despite this, governments have overseen a steady growth in emissions over the last decade (IPCC 2023). This year, fossil carbon dioxide (CO_2) emissions look set to rise a further 1% (Bawden 2023). If global emissions do not peak before 2025, the Paris Agreement's ten-year anniversary will be marked by a collective failure to meet a key IPCC deadline.

However, there are emerging signs that a peak in GHG emissions is on the horizon. The energy transition is well under way in many areas; recent years have seen an explosion in the uptake of zero-carbon technologies such as solar and wind, electric vehicles and heat pumps, and a growing number of countries have already peaked their total GHG emissions and are steadily bringing them down.

As a result, International Energy Agency (IEA) projections show a decline in fossil CO_2 emissions by 2025, possibly even in 2024. This would make 2023 the year of peak fossil CO_2 emissions, providing confidence that a peak in global GHG emissions before 2025 is within reach.

This December, governments will conclude the first Global Stocktake of collective climate action under the Paris Agreement at COP28 in United Arab Emirates. An agreement at the Summit to peak global emissions before 2025, in line with the IPCC's findings, would send a strong signal that governments remain committed to 1.5°C goal and are acting with urgency in response to worsening climate change impacts.

Our analysis shows that peaking emissions before 2025 is feasible. We also identify some of the key levers to increase our chances of meeting this timeline. In large part, many of the necessary transitions are under way, and if the right policies are put in place to foster a continuation of recent growth trends in zero carbon technologies, we show that demand for fossil fuels and emissions could start to fall as soon as next year.

Greater efforts will be essential to achieve the depth of reductions needed by 2030 and beyond to keep the 1.5°C limit in reach, but there is cause for optimism that the record emissions levels expected for 2023 may never be broken again.

In this report we:

- define what it means to peak and decline GHG emissions
- outline signs that global GHG emissions could peak in the near future
- analyse the factors that enabled historic peaking in countries and sectors
- develop scenarios to estimate when global GHG emissions could peak
- analyse what this would mean for the energy transition globally
- explore how these scenarios might play out in select major economies
- set out key policy actions needed to keep 1.5°C in reach

Signs that a peak is coming

The main features of a peak in emissions are obvious: we would see a slowdown in emissions growth before emissions stop increasing altogether and start falling.

Achieving a definitive peak in total GHG emissions, with a sustained decline afterwards, would require fossil CO_2 emissions to peak as well. This is because fossil CO_2 emissions represent the largest fraction of global emissions. If they were to continue to rise, declining emissions from other gases and sectors would at best only be able to temporarily compensate for this. We therefore need to see structural changes to the global economy and energy system.

The IEA's latest World Energy Outlook (WEO) suggests that fossil fuel CO_2 emissions could peak before 2025, and as early as 2023 (Carbon Brief 2023, IEA 2023d). In the IEA's Stated Policies Scenario (STEPS), a combination of national policies and market dynamics, leads to a peaking in global fossil fuel demand this decade, as deployment of zero-carbon technologies accelerates (IEA 2023d).

At the sector level, there are indications that the power sector could peak this year (Ember 2023b), as over half of the world is now past a peak in fossil-fuelled power (Ember 2023c). In particular, the world's largest power sector, China, may peak emissions in 2023 and start declining from 2024 onwards, as surging renewables generation exceeds demand growth (Myllyvirta 2023a). Falling power sector emissions, coupled with increased electrification, could unlock system-wide decarbonisation in other sectors and help achieve a peak in other sectors also.

While these are positive signs, more pessimistic outlooks exist. For example, the US Energy Information Administration's (EIA) International Energy Outlook projects that energy-related CO_2 emissions will either continue to increase or plateau at around current levels (US EIA 2023). OPEC has also predicted that global oil demand will continue to grow out to 2045, albeit at a declining pace (OPEC 2023).

The differences between these viewpoints can be largely explained by how well forecasters account for current technology trends, and by considering the clear strategic incentive of some actors to forecast continued fossil fuel demand growth. It is perhaps unsurprising that OPEC, an organisation whose existence depends on the fossil economy, should predict that oil demand will grow for decades.

Meanwhile the EIA's forecast is partly based on a very limited roll-out of renewables, with global solar growth at around 10% per year across the 2020s. It is very difficult to reconcile this assessment with the latest market trends: solar has grown at closer to 20% per year from 2020-2022 (IRENA 2023a).

The IEA itself has historically been widely criticised for underestimating the deployment of solar under current policies. In recent WEOs, it seems that the IEA has made steps to address this issue and is now forecasting solar PV additions which are more consistent with market trends. The result – a peak in fossil fuel demand and CO_2 emissions by 2025.

However, as we lay out in this report, the growing momentum behind zero emissions technologies suggests that a faster transition than the STEPS scenario is not only possible, but already underway. STEPS presents a world in which the momentum towards clean energy continues but does not truly accelerate. But the energy transition *will* accelerate, as economies of scale and technological learning continue to drive cost reductions in zero-carbon technologies. As shown in later sections, this continued growth in clean energy will only help us peak sooner and decline faster.

It is not only fossil CO_2 that matters. Peaking fossil CO_2 is key, but we need to peak *all* emissions before 2025, not just fossil fuel emissions. Reductions in potent, short-lived greenhouse gases such as methane – which has been on a steady upwards trajectory (Minx *et al* 2021) – will be needed, and the Global Methane Pledge is an important step towards this. Emissions from deforestation and forest degradation also need to be reined in, and commitments such as the Glasgow Leaders' Declaration on Forests and Land Use urgently need to be implemented.

In this report we show that these signs could lead to a global peak in total GHGs very soon, and we lay out some of the conditions that could make this happen. But first, we take a look at where peaking has already taken place at the national level to understand the drivers of peaking in the past and how these might change looking forward.

Where have emissions already peaked?

One of the signs that a global peak in emissions is approaching is the fact that a growing number of countries have already achieved peak emissions.

Different approaches can be used to define when a country has peaked emissions. We focus on whether a country has achieved a long-term and consistent downwards trend in emissions. A country can be said to have peaked emissions if the five-year trend in emissions is consistently negative over the time period analysed. A country is deemed to have peaked at the point that this condition is achieved.[1]

[1] This approach is conceptually consistent with the approach used to define when peaking occurs in our forward-looking global scenarios, as it focuses on detecting a robust downwards trend which overcomes inter-annual variations in emissions. However, it is applied slightly differently here (where the data being assessed is real-world emissions including noise) than in our forward looking scenarios (where the data is scenario projections which do not incorporate inter-annual variability in greenhouse gas emissions).

We apply this criterion to determine how many countries have peaked 1) territorial GHG emissions (including emissions from land-use, land-use change and forestry (LULUCF)), 2) territorial fossil CO_2 emissions, and 3) consumption-based fossil CO_2 emissions. For more details see the Methods in Annex II.

The first of these is the most relevant to this work, which is focused on peaking total GHG emissions. However, as fossil CO_2 emissions are the central driver of global GHG emissions, observing which countries have peaked fossil CO_2 emissions is also important. Additionally, there are ultimate limits on how much land-use CO_2 and non-CO_2 emissions can be reduced. If a country has peaked emissions by relying on these sources without peaking fossil CO_2 emissions, the peak is unlikely to be followed by a sustainable, long-term downward trend.

Finally, given concerns that for some countries, declining emissions may be simply due to the outsourcing of emissions to other countries, we also quantify how many countries have peaked consumption-based fossil CO_2 emissions. A growing number of countries have peaked consumption-based emissions and are now in the phase of lowering them (Figure 1).

In 2005, only 13 countries had peaked total GHG emissions. These were the USA and a grouping of European countries, including Germany, the UK, France and Italy. But in the years that followed, the number of countries which have peaked total emissions has increased markedly. 50 countries had peaked emissions by 2015 and entered the phase of long-term decline. This includes some major emitters, such as the USA, Germany, Japan and Australia, but also some emerging and developing economies such as South Africa and Argentina.

These countries were responsible for over a quarter of total greenhouse gas emissions in 2020. While the pace of decline from 2015-2022 in these countries was not enough to achieve a global peak in emissions, they demonstrate that large swathes of the global economy have already peaked and entered the declining phase. As more countries achieve a peak at a national level, we will soon cross the global tipping point where global emissions peak and decline.

Even more countries have achieved a peak in fossil CO_2 emissions on a territorial basis. 60 countries have achieved a peak in their fossil CO_2 emissions as of 2015. These countries were responsible for almost 30% of global CO_2 emissions in 2022. Fewer countries have achieved the stronger criterion of peaking their consumption-based fossil CO_2 emissions, with only 42 countries achieving this by 2015.

However, these countries were responsible for over 35% of global emissions, when accounting for their overseas footprint of exported emissions. This shows that not all peaking in emissions at the national level is due to outsourcing of emissions to other countries, but that some real progress has been made in emissions reductions. While this progress has not been enough to achieve peaking of global emissions, this gives us confidence that peaking before 2025 is possible.

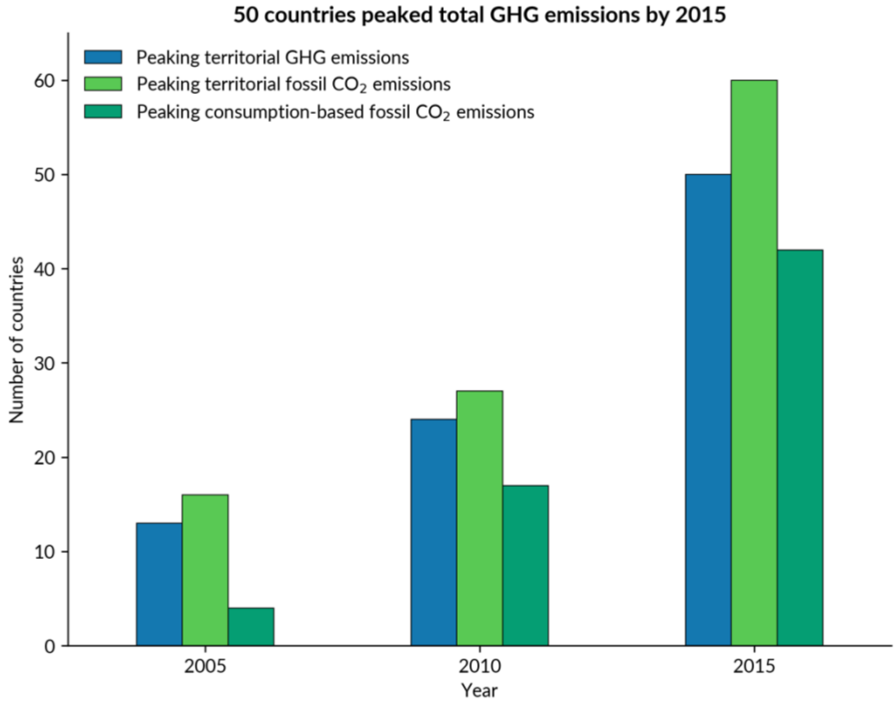

Figure 1: The number of countries to achieve a peak in total GHG, fossil CO_2 and consumption-based fossil CO_2 emissions.
Compiled using country-reported data on total GHG emissions excluding LULUCF, as calculated by PRIMAP, and LULUCF data from national inventories.

Countries that have already peaked emissions can provide lessons on how the globe as a whole could do the same. In Annex I, we analyse what has driven emissions reductions in countries that peaked fossil CO_2 emissions between 2006-2021. We focus on fossil CO_2 as this is the most important component of global emissions.

This analysis shows that the main drivers of the decline in fossil CO_2 emissions have been improving the energy intensity of the economy and reducing the share of fossil fuels in the energy mix (with a median contribution of 75% and 35% respectively). This suggests that countries which have already peaked have been generally more successful in improving energy efficiency and cutting down on energy intensive processes than on shifting from fossil fuels to renewables, although both have played a central role.

The analysis also shows a strong variation between countries, and in some – such as Sweden, Finland and Denmark – the role of declining fossil fuel shares has been much larger.

Looking forwards, we analysed the same set of drivers and how they contribute to emissions reductions over the next 15 years in 1.5°C compatible pathways (see Annex I). Energy intensity improvements remain essential, but the declining share of fossil fuels in energy use – driven by accelerated deployment of renewables and increased electrification – becomes the predominant driver.

This is why we focus on measures to cut fossil fuel use in the energy sector in our forwards looking analysis of how to peak emissions by 2025. However, this analysis highlights that energy efficiency and other measures to reduce demand – which are not a focus in this report due to data limitations – are also essential.

When could global emissions peak?

To estimate when global greenhouse gas emissions could peak and under what conditions, we develop three scenarios for global GHG emissions over the period out to 2035. These scenarios are intended to explore plausible developments that either follow current policies and trends, represent key actions that could cut non-CO_2 emissions in the near-term, or capture the potential for change if rapidly diffusing zero-carbon technologies continue their explosive growth.

It is important to highlight that none of these scenarios limit warming to 1.5°C. Much greater efforts will be needed to align us with a Paris-compliant pace of emissions reductions. These actions are set out in scenarios such as the IEA's Net Zero Emissions (NZE) and those 1.5°C compatible scenarios assessed by the IPCC.

However, peaking is a critical inflection point for the world, marking the point at which we take our foot of the accelerator and can begin the process of a fossil phase out in earnest. These scenarios demonstrate the feasibility of peaking emissions before 2025 and signal the beginning of the road towards a zero-carbon future.

The three scenarios we introduce are termed **baseline, low effort** and **continued acceleration.**

In the **baseline** scenario, fossil CO_2 emissions peak before 2025 and start declining, following the IEA STEPS scenario. However, there is no action taken to reduce non-CO_2 emissions, which continue to grow along the trendline of the past decade.

In the **low effort** scenario, some action is taken to reduce non-CO_2 emissions, with no-regrets abatement options in methane (CH_4) and nitrous oxide (N_2O) taken up, and the Kigali Amendment on hydrofluorocarbons (HFCs) also implemented. This leads to a peak in all subcomponents of greenhouse gas emissions (CO_2, CH_4, N_2O and F-gases), but fossil CO_2 continues to follow the STEPS trajectory, which likely underestimates the pace at which the energy transition will occur.

Finally, in the **continued acceleration** scenario, we take a more ambitious trajectory for fossil CO_2 based on accelerated deployment of wind, solar and electric vehicles across the world which aligns with current technology trends. We also model slightly strengthened action on global methane emissions, as current signatories of the Global Methane Pledge implement their commitments. We select these technology levers because they represent measures that are both rapidly implementable to control emissions growth and achieve decline in the coming 24 months, and because they have sufficient data availability to allow their impact to be well quantified. See the Methods in Annex II for further details on lever selection.

In all scenarios, we take a conservative approach to LULUCF emissions, assuming that these will plateau at current levels, rather than decline. This means that none of the scenarios rely on progress in reducing LULUCF emissions to peak global emissions. However, we do explore the potential for action to cut LULUCF emissions to further contribute to a peaking of global GHG emissions (see Box 2 on LULUCF emissions).

The underlying assumptions for each scenario are documented briefly in Table 1. For more details on the underlying trajectories for different gases, see Methods in Annex II.

Table 1: Summary of assumptions in the three main scenarios produced.

Scenario	Baseline	Low effort	Continued acceleration
Fossil CO_2	Emissions follow the IEA STEPS scenario	Emissions follow the IEA STEPS scenario	Emissions follow the IEA STEPS scenario, augmented by accelerated deployment of wind, solar and EVs.
CH_4	Emissions follow the 2012-2022 trend	No-regrets (<0 $/tCO2e) abatement opportunities are taken up	Implementation of the methane pledge by current signatories, 2012-22 trend for non-signatories
N_2O	Emissions follow the 2012-2022 trend	No-regrets (<0 $/tCO2e) abatement opportunities are taken up	No-regrets (<0 $/tCO2e) abatement opportunities are taken up
F-Gases	Emissions follow the 2012-2022 trend	The Kigali Amendment is implemented, reducing HFC emissions, other F-gases follow the 2011-2021 trend	The Kigali Amendment is implemented, reducing HFC emissions, other F-gases follow the 2011-2021 trend
LULUCF	Net LULUCF emissions plateau at the 2021 level		

Figure 2 shows the trajectories that we use for non-CO_2 emissions in each scenario. Taking up no-regrets abatement options in methane and nitrous oxide, and implementing the Kigali Amendment, could lead to peaking non-CO_2 emissions this decade. Methane and N_2O emissions would peak in 2026, while F-gas emissions could peak in 2025. Meanwhile, implementation of the global methane pledge by current signatories could lead to methane emissions peaking in 2024 and falling 13% by 2030 relative to 2020 levels.

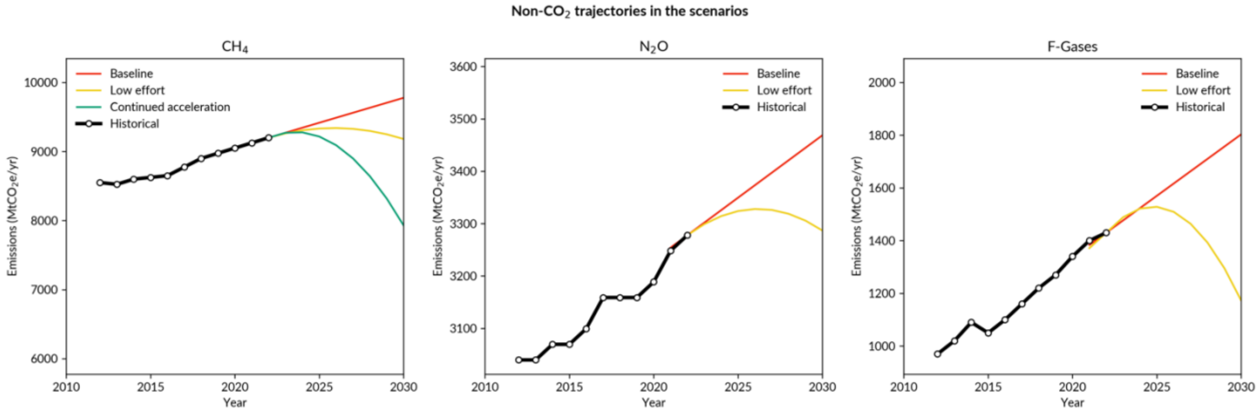

Figure 2: Future trajectories for non-CO_2 emissions under our three scenarios, compared with historical emissions from PRIMAP.

Implications for global emissions

The resulting global emissions trajectories for these three scenarios are seen in Figure 3. These trajectories are smooth trajectories which come from scenario modelling – they do not account for the range of weather, economic and geopolitical factors which contribute to the 'noise', or interannual variation, in emissions.

We estimate the impact of interannual variation in greenhouse gas emissions and add this back onto the scenarios to give a picture of how emissions might develop in the real world. Figure 4 shows the probability that emissions would actually decline in a given year, once interannual variation in GHGs is accounted for. We use this to help classify the scenarios' peaking behaviour (see Box 1).

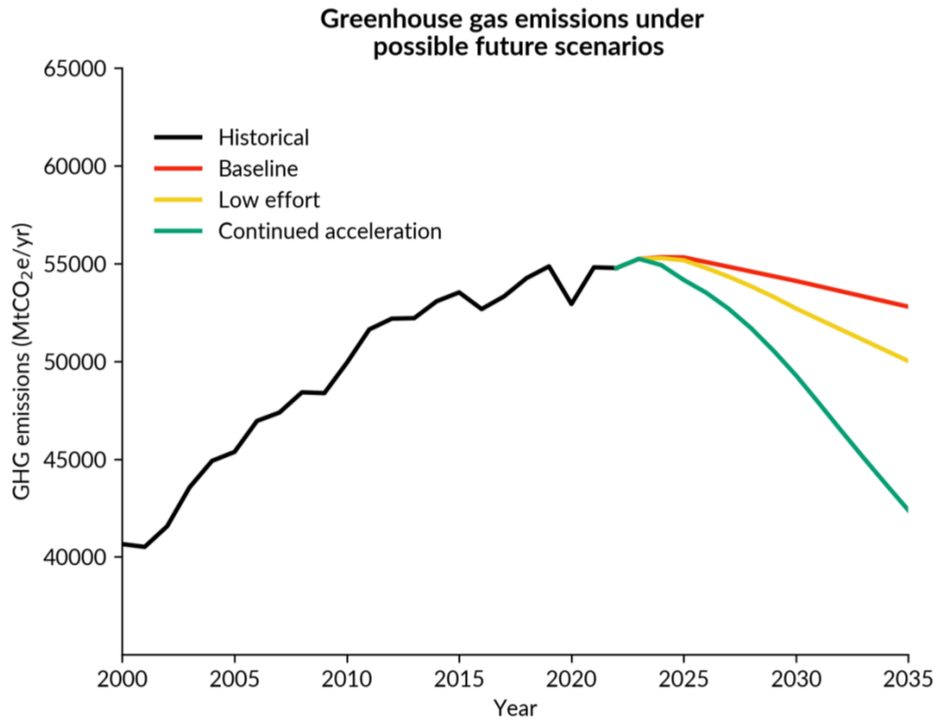

Figure 3: Global greenhouse gas emissions out to 2035 under each of our scenarios. These are baseline (red), low effort (yellow) and continued acceleration (green). Historical emissions from PRIMAP (GHGs excluding LULUCF) and Global Carbon Budget (LULUCF) are shown in black.

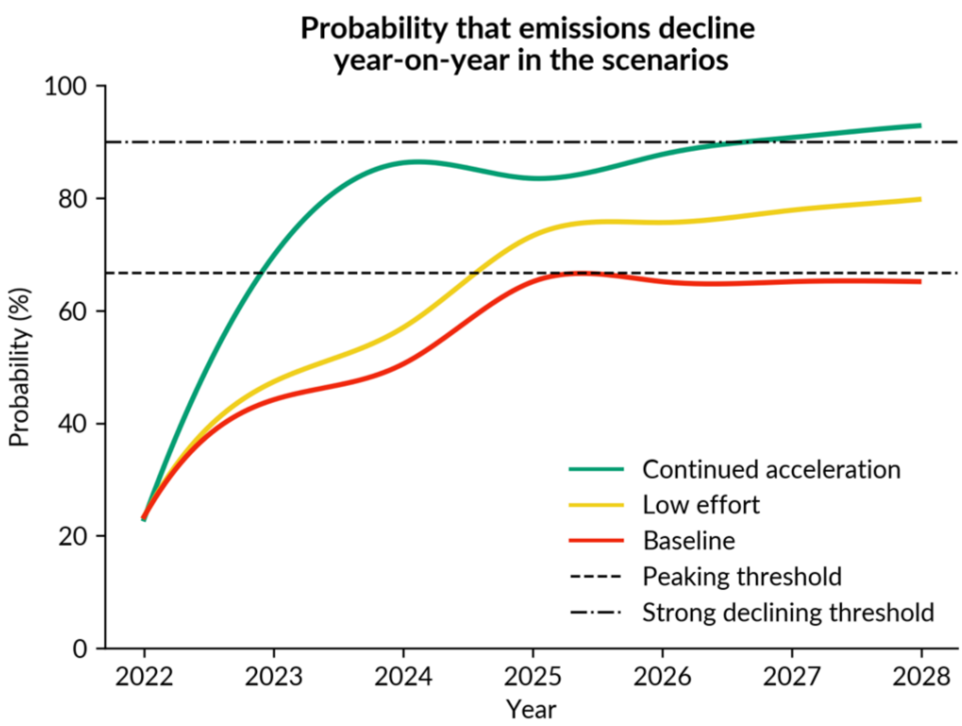

Figure 4: Probability that emissions would decline year-on-year (once interannual variation is accounted for).

Box 1: A plateau is not enough: to truly peak, emissions must start to decline consistently

As action to cut greenhouse gas emissions increases around the world, emissions will peak and then enter a stage of long-term, accelerating decline. To establish if peak emissions has occurred, it is not enough for greenhouse gas emissions to merely stop rising – they must move through the plateau into a verifiable peak and long-term decline.

The Paris Agreement acknowledges this, calling for the world to peak greenhouse gas emissions 'as soon as possible' and then to 'undertake rapid reductions thereafter in accordance with best available science'. The question then arises – how do we define a peak vs. a plateau?

In this work, we use a statistical approach to distinguish between a peak and a plateau. We use the historical interannual variability in greenhouse gas emissions to estimate how future greenhouse gas emissions could vary between years around a central trendline. This interannual variation in greenhouse gas emissions is parameterised using the last fifty years of emissions data and is shown in Figure B1. For more details see Methods, Annex II.

In the real world, year-on-year changes in GHG emissions are a combination of a structural component (which is captured in scenarios, in which the roll-out of technologies happens smoothly and there is no noise), and a noise component (which captures how variations in weather, economics and geopolitics result in additional variation in greenhouse gas emissions and is not included in scenarios).

If the structural component of emissions changes is flat (0 $MtCO_2e$/y variations), then in reality you would expect annual emissions to rise ~50% of the time and fall ~50% of the time. In any given year, it would be 'as likely as not' that emissions decline compared to the previous year. This defines a plateau, which is not consistent with the requirements in the Paris Agreement.

If the noise component of interannual variation in GHG emissions continues as in recent decades, then to have a two-thirds chance that emissions would still decline year-on-year, once this variation has been accounted for, the structural component would need to be around -267 $MtCO_2e$/y, or -0.5% per year. In IPCC likelihood terms, it would then be 'likely' that in any given year, emissions would decline compared to the previous year. This is the threshold that we use to determine when global emissions have peaked.

If the structural component of change is even stronger, at -950 $MtCO_2e$/y, then there would be a 90% chance that in the real world, emissions would decline year-on-year once interannual variation in GHG emissions is accounted for. In IPCC likelihood terms, it would be 'very likely' that in a given year, emissions would decline relative to the previous year. This is the threshold

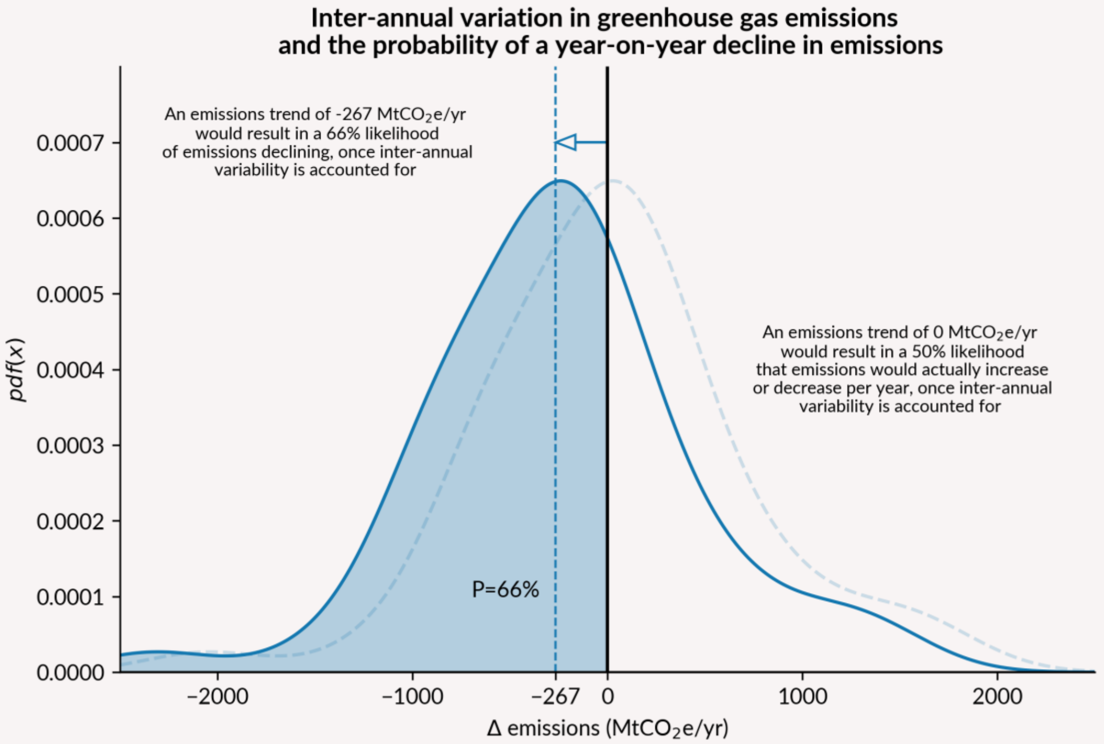

Figure B1: Interannual variation in total greenhouse gas emissions

In the Baseline scenario, emissions grow from 2023–2024 before reaching their maximum in 2024. However, they then enter a long-term plateau in which emissions are falling negligibly. It is not enough for emissions to plateau – emissions must peak and then decline. See Box 1 for more detail on how we differentiate between a peak and a plateau.

Once interannual variation in GHGs is accounted for, there would still be a ~60% probability that emissions in 2025 would be greater than emissions in 2023, and a true peak (as defined by our criterion) would be achieved in the late 2020s / early 2030s. In addition, this scenario would never achieve a strong decline in global emissions. There would still be a ~33% chance that emissions would grow in any given year, even in the 2030s.

Peaking fossil CO_2 emissions at the pace defined in IEA STEPS with no meaningful action to address non-CO_2 emissions can prevent continued growth in global emissions. But it is not enough to achieve the IPCC's milestone of peaking global emissions before 2025.

In the low effort scenario, there is comparable action to address non-CO_2 emissions as there is for CO_2 emissions. As a result, emissions reach their maximum around 2024, and there are stronger reductions in emissions afterwards than in the baseline scenario. Accounting for interannual variation, there would be a ~75% chance that emissions would decline from 2025–2026.

We classify this scenario as truly peaking in 2025, because this is the year when it achieves a two-thirds chance of emissions declining year-on-year in the real world, once interannual variations are factored in (see Box 1). However, the low effort scenario does not enter the 'strong declining' phase pre-2035, as emissions reductions never reach our threshold of –950 $MtCO_2e$/yr.

In the continued acceleration scenario, emissions start to decline from 2023 onwards. Even once interannual variation is accounted for, there would still be a 70% chance that emissions decline in the real world from 2023 to 2024. This could make 2023 the year of peak global GHG emissions.

There is no plateau phase, but instead emissions immediately enter a phase of clear and considerable long-term decline. By 2027, emissions are falling over 950 $MtCO_2e$ /yr, which is enough to classify them as having past the peaking phase and entered the strong declining phase (see Box 1 for more details).

Energy transitions that can achieve peaking by 2023

2024 could be the year that total greenhouse gas emissions begin to decline year-on-year. This would make 2023 the year of peak emissions. While economic, geopolitical and weather-based variations (among others) could influence this date slightly, achieving the IPCC's milestone of peaking total GHG emissions 'before 2025' is well within reach.

The continued acceleration scenario sees all greenhouse gases (CO_2, CH_4, N_2O and F-gases) peak in the 2020s. However, at the heart of this scenario is a clear and growing driver – fossil fuel demand and emissions begin to fall faster and faster as the momentum of the global energy transition builds. We now further explore the energy transition dynamics in the scenario which achieves peaking by 2023.

The global energy transition

The continued acceleration scenario is based on a bottom-up assessment of the pace of deployment for wind, solar and electric vehicles (EVs) which could be achieved if these technologies continue to scale rapidly up the S-curve. This is done at the national and regional level.

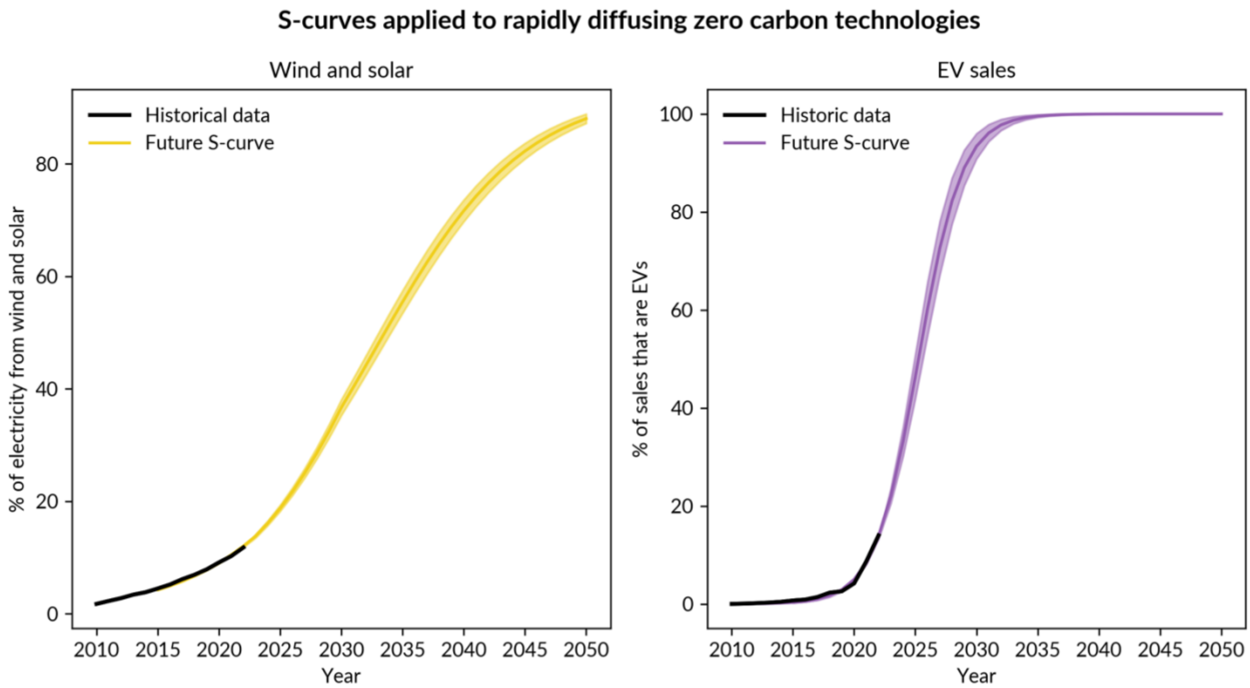

Figure 5: S-curves for the future deployment of wind, solar and EVs.

Figure *5* shows the results when aggregated to a global level. Wind and solar would provide around 37% of global electricity generation by 2030 and over 80% of generation by 2050, if their deployment continues to accelerate up these curves.[2]

Meanwhile, EVs would grow towards 90% of global car sales by 2030, if they continue to scale up the S-curve in line with historical trends and would approach 100% of global sales by 2035. These values are in line with other analysis in the literature (RMI 2023b, 2023a, Boehm *et al* 2023). The energy transition is underway, and its momentum is becoming unstoppable.

[2] The share of wind and solar at the global level is slightly higher than observed in other recently published S-curve analysis (Climate Action Tracker 2023). This is because this analysis produces S-curves at a national level, and then compares them to existing policies and strategies as captured in the IEA STEPS and national data sources. Where existing national policies would suggest that countries can go faster than the S-curve, this analysis accelerates deployment further.

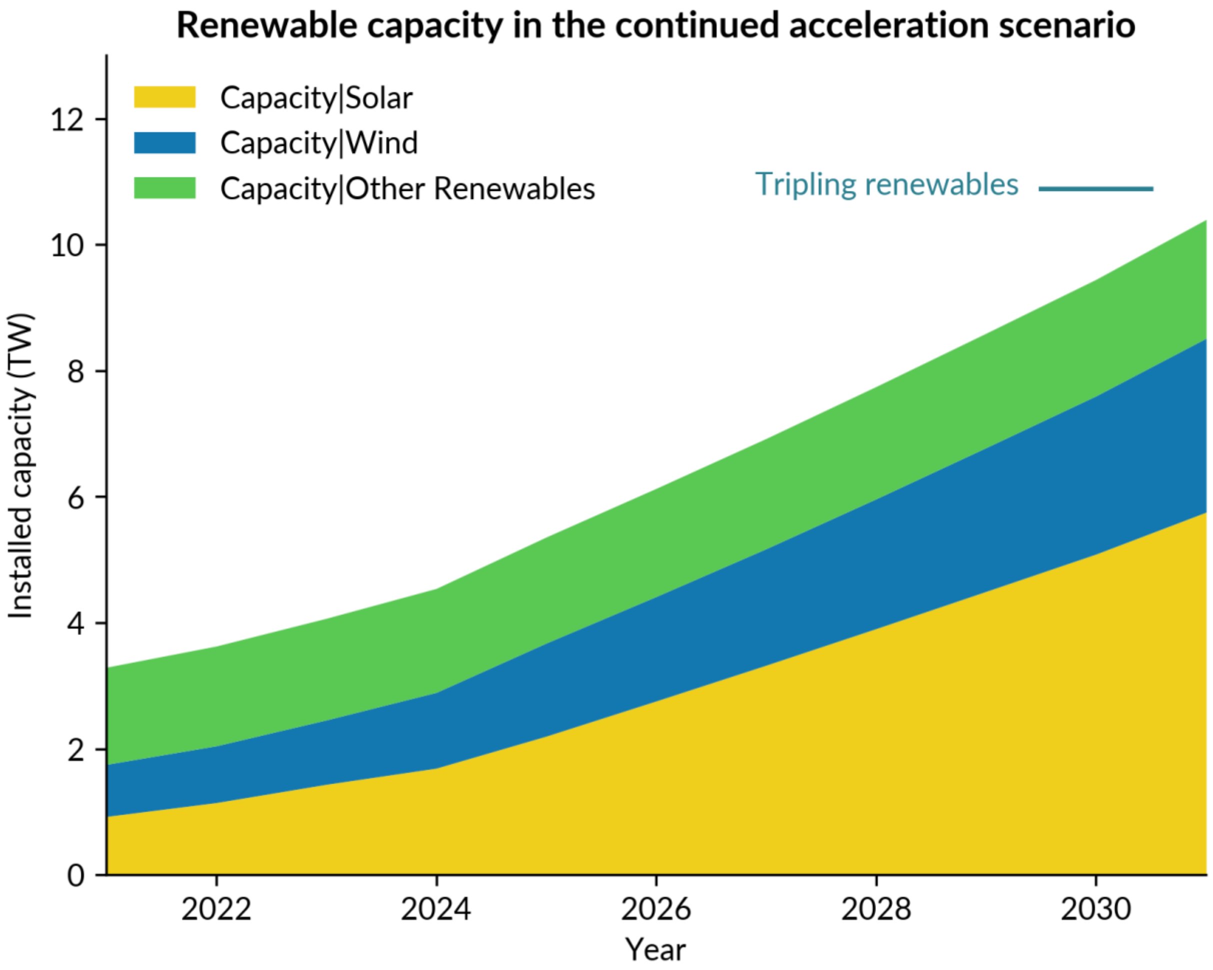

Figure 6: Installed renewable capacity in the continued acceleration scenario.

In terms of installed capacity, wind and solar reach 7.5 TW by 2030 under this scenario.[3] This is broadly aligned with the levels of wind and solar observed in the IEA's announced pledges scenario. This shows that wind and solar deployment is already growing fast enough to meet countries' current national targets and pledges.

[3] The continued acceleration scenario is defined at the generation level – we use our S-curve analysis to increase the share of wind and solar in each country / region, using the IEA STEPS scenario as a starting point. Calculating capacity deployment requires assumptions on the overall level of electricity demand, the relative share of wind vs. solar, and their respective capacity factors. We take these from the IEA STEPS scenario. If the acceleration in solar and wind generation is driven more by solar than wind, this split could move in favour of solar, which would in turn increase overall capacity deployments (due to the lower capacity factor of solar PV). Similarly, higher assumptions around electricity demand would translate into higher overall wind and solar generation and higher capacity deployments.

Total renewable capacity in 2030 reaches around 9 TW in our scenario, around 2.5 times current levels. While this is not a tripling of renewable capacity, it is not far from achieving this. As the pace of the energy transition has accelerated, particularly in the last two years, extrapolating forwards the pace of change in just the last two years would give even higher capacity numbers than our approach. A tripling of renewable capacity by 2030, driven by turbocharged wind and solar deployment, is still well within reach.

Across 2023 and 2024, the continued acceleration scenario sees around 1 TW of wind and solar installed cumulatively. This is broadly aligned with the IEA's latest forecasts of what could plausibly be achieved in 2023 and 2024, of around 950 GW (IEA 2023b).

In 2024, the rapid growth in zero-carbon technologies in this scenario is sufficient to fully meet the growth in overall energy demand, and starts to eat away at demand for fossil fuels. This means total fossil fuel demand could reach its peak in 2023, and then enter a period of rapid decline by 2025 (Figure 7).

Coal demand peaks in 2023 in this scenario and falls thereafter. Meanwhile fossil gas demand, for which the IEA is projecting a peak by 2029, peaks in 2024 and begins to decline rapidly afterwards. Oil demand would peak in 2025 in this scenario. In 2030, EVs in total would displace over 5 million barrels of oil per day of demand. Much of this displacement is already accounted for in the STEPS scenario (~3.5 million barrels per day), so the additional impact of an accelerated EV transition is smaller. Nevertheless, the continued acceleration scenario would see distinctive peaks in all three fossil fuels by 2025.

Our analysis shows that a peak and decline in fossil fuel demand is close – and could come as early as this year or next. However, governments are collectively still planning to massively expand fossil fuel production. When all plans and projections are added up, they would lead to an increase in coal production out to 2030, and in oil and gas production until 2050 (SEI *et al* 2023).

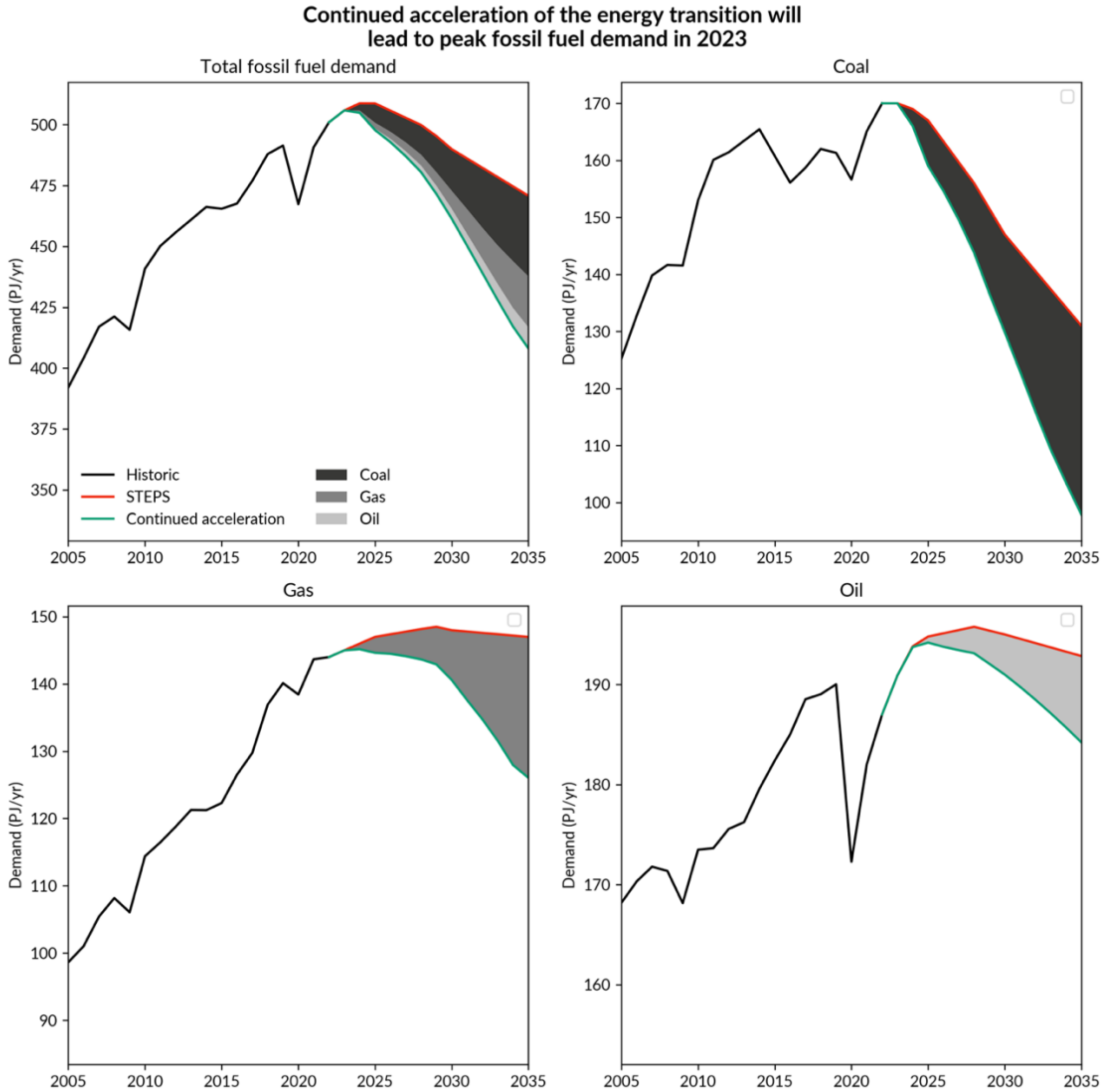

Figure 7: Fossil fuel demand in the continued acceleration scenario relative to the IEA STEPS.

This represents a major risk to our ability to peak and decline global emissions quickly. Crucially, the realisation of these supply-side plans is not a foregone conclusion; as renewables push fossil fuels out of the energy system, falling fossil demand is likely to render many of these new fossil fuel projects uneconomic, with a high risk of becoming stranded assets.

Reduced fossil fuel subsidies and strengthened climate policy would contribute to this risk. Nevertheless, action to boost fossil fuel supply could reduce willingness to accelerate climate action, by entrenching vested interests in the energy system and reducing fossil fuel prices. Current fossil fuel expansion plans represent both a huge climate and economic risk that does not need to be taken.

As fossil fuel demand peaks and declines, starting with coal, so too do fossil CO_2 emissions. In our continued acceleration scenario, fossil CO_2 emissions peak in 2023 and enter a period of rapid decline, so that by 2030 they are around 2 $GtCO_2$/yr lower than in the STEPS scenario (Figure 8). Total CO_2 emissions still grow in 2023 by around 0.5%, which is within the uncertainty range of current estimates (Bawden 2023).

The vast majority of the emissions savings come from the power sector, where wind and solar primarily displace coal, but also fossil gas and oil-fired generation in some regions (e.g., the Middle East and Africa). Out to 2035, the impact of an accelerated EV transition appears to be relatively small. This is due to three reasons.

First, we are focused only on emissions savings from the transition to electric *cars*. The current Internal Combustion Engine (ICE) fleet is responsible for around 4 $GtCO_2$ of global emissions – sizeable, but only a third of global power sector emissions. Considering the broader transition to electric mobility would increase emissions savings further.

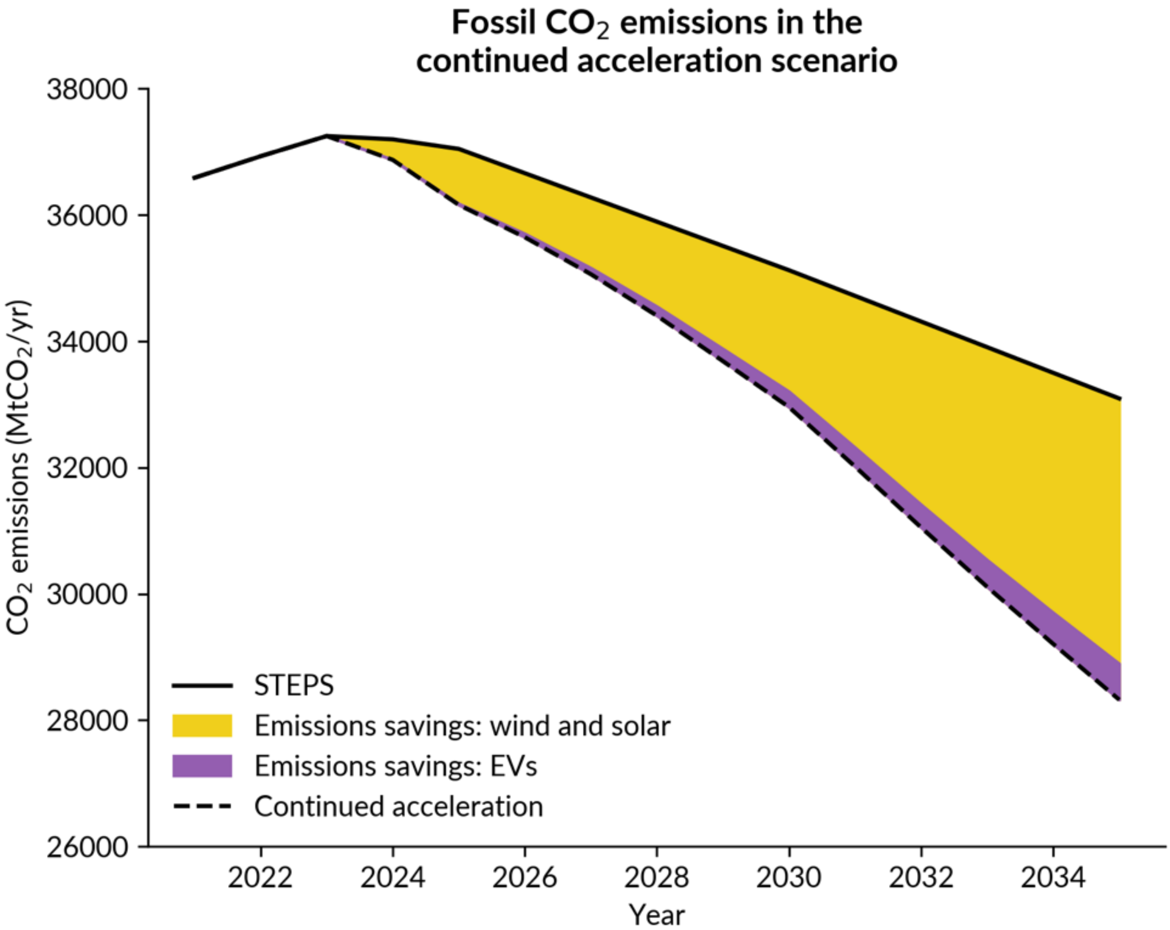

Figure 8: Fossil CO_2 emissions and savings under the continued acceleration scenario.

Second, there is a difference between sales and stocks. The explosive growth in EVs is currently in the share of total car *sales*, rather than stocks. As global car sales represent roughly 6% of the global car stock, the growing dominance of EVs in overall car sales does not translate immediately into large-scale emissions savings, as it takes some years for high EV sales to flow through into changes in the overall car stock.

Finally, it is due to the level of ambition already accounted for in the STEPS scenario. Figure 8 shows the increase in ambition relative to the STEPS in the continued acceleration scenario. Much of the ~5 mb/d of oil that is displaced in the continued acceleration scenario is already captured in STEPS.

National and regional energy transitions that achieve peaking

At the global level it is clear that explosive growth in zero-carbon technologies could lead to fossil CO_2 emissions peaking this year and fossil fuel demand entering a phase of accelerating decline in the mid 2020s. The following section explores the key dynamics of this energy transition across major economies. Table 3 shows what our accelerated scenario means for a number of indicators for these countries, as well as for major world regions and at the global level.

China

The country with the greatest impact on when global emissions could peak, according to our analysis, is China. This is mostly driven by the power sector transitioning from coal to renewables. Solar and wind capacities are growing so fast that China could achieve its 2030 goal of 1200 GW of solar and wind capacity more than five years early; under our continued acceleration scenario, total solar and wind capacity reaches close to 1500 GW by 2025, and achieves a quadrupling of 2022 levels by 2030.

If solar and wind continue to grow up an S-curve, average annual solar and wind capacity additions in 2024 would rise to 220 GW per year. While this represents a significant jump from the roughly 120 GW of solar and wind China installed in 2022 (Ember 2023a), the country has added over 160 GW of new solar and wind capacity in the first three quarters of 2023, and is on track to install just over 200 GW in total in 2023 at current rates (NEA 2023).

At this pace of growth, new renewable generation in 2024 would be enough to meet the country's projected growth in electricity demand, and at the same time displace fossil fuel use. This supports recent analysis that suggests fossil fuels are on the cusp of a structural decline in China's power sector, which would lead to China's total CO_2 emissions starting to fall in 2024 – well ahead of its target to peak 'before 2030' (Myllyvirta 2023b).

A key question is the extent to which China's coal power plant pipeline will be built and used. China remains the biggest force in the global coal-fired pipeline, with 136 GW of coal fired power plants in construction and a total pipeline of around 400 GW as of July 2023 (Global Energy Monitor 2023). If these plants enter operation with the historical capacity factor of around 55%, the ensuing emissions could drive China's emissions upwards, preventing a peak in China's emissions and making it ever harder for the world as a whole to peak emissions.

This, however, is very unlikely to happen. As solar and wind generation continues to escalate, the utilisation of China's coal fleet will fall, with coal further and further restricted to providing power only at peak times/seasons or in periods of lower wind and solar output. The development of a national power market and inter-provincial power trading in the coming years will likely further accelerate the transition from coal to renewables (Howe 2023).

In 2022, coal-fired power generation made up 62% of China's electricity sector, but if wind and solar deployment continues to grow at recent rates, the share of coal power could drop to 50% by 2025 and 35% by 2030, by which time wind and solar generation would be providing over 40% of electricity demand.

Any new coal plants will face very low utilisation rates, meaning a loss to their profitability or asset stranding. For example, if coal capacity increases in line with STEPS, growing by 116 GW (around 10%) from 2022 levels by 2030, the overall capacity factor of the coal fleet would fall to 36% by the end of the decade under our continued acceleration scenario, down from around 55% in 2022. If more of the pipeline is developed, coal plant utilisation would fall even lower.

Alongside solar and wind, EVs are also taking off in China. Our scenario captures an accelerated growth in EV sales, reaching around 71% by 2025. This is greater than China's target for clean energy vehicles to make up 25% of new vehicle sales by 2025, but EV sales had already reached 29% in 2022 (IEA 2023a). Rapid EV scale-up could result in an increasing and sustained reduction in oil demand (currently around 2000 million barrels per year in China's transport sector (WEO 2022) so that by 2030, almost 700 million barrels of oil would be displaced – compared to a scenario with no EV uptake.

India

India's economy is growing rapidly, and with it overall emissions. India's CO_2 emissions grew 56% from 2010 to 2022, and it currently represents 7.1% of global CO_2 emissions (IEA 2023d). However, the dynamics of India's energy transition are changing. While coal provided 80% of additional electricity demand from 2012-2022, over the next decade wind and solar are forecast to provide over 66% of electricity demand growth (Ember 2023d).

Despite these changes, in the IEA STEPS scenario India's CO_2 emissions continue to grow across the 2020s, growing 20% over the 2022-2030 period and peaking at some point in the second half of the 2030s. In the short-term, coal remains dominant in the power sector, still providing over 50% of electricity in 2030. This contributes to the relatively late date of peaking.

In the continued acceleration scenario, India peaks total CO_2 emissions at some point in the early 2030s instead, bringing forwards the peak in emissions by around five years. CO_2 emissions in 2030 are still 13% above 2022 levels. This equates to cutting India's CO_2 emissions intensity by approximately 45% by 2030 relative to 2005,[4] which is consistent with India's Nationally Determined Contribution (NDC) target of a 45% reduction, although this applies to all greenhouse gases.

In the continued accelerated scenario, installed wind and solar capacity reaches 220 GW by 2025 and 470 GW by 2030, up from 2022 levels of around 120 GW of installed wind and solar. Over 2023/2024 on average, 26 GW of wind and solar are installed each year. As a result of this rapid deployment, the share of wind and solar in the Indian electricity mix grows from 10% in 2022 to 17% by 2025 and 32% by 2030. This is closely aligned with India's latest National Electricity Plan, which envisages that solar and wind would provide 35% of electricity generation in the 2031-32 period (Government of India 2023).

According to our analysis, as wind and solar deployment accelerates, demand growth for fossil fuels in India will begin to slow, before fossil demand peaks and begins to decline. Demand for coal in the power sector would peak around 2028. The share of fossil fuels in the power sector would fall from 75% in 2022 to 65% in 2025 and 52% by 2030. Total fossil fuel demand across the economy would still grow by 18% from 2022 to 2030 but would peak in the early 2030s, along with total fossil CO_2 emissions, and enter decline.

[4] We take fossil fuel CO_2 emissions in 2005 from the PRIMAP-hist dataset (Gütschow and Pflüger 2023); for India's GDP, we take historical data from RBI (1990-2018) (RBI 2022) and the IMF (2019-2022) and projected GDP (2023-2028) from the IMF (IMF 2023); we project GDP to 2030 using the five-year trend.

EU27

In our continued accelerated scenario, the share of electricity generation from wind and solar in the EU rises from 22% in 2022 to 37% by 2025 and 53% by 2030. In terms of capacity, this would require the addition of over 500 GW by 2030 – more than double from where it stood in 2022 – to reach 990 GW.

Other analysis suggests that even more is possible. European Commission modelling indicates that to meet the EU's 2030 target of 42.5% renewable energy in final energy consumption, capacity of solar and wind should reach even higher to 1102 GW (European Commission 2022). Other analysis suggests solar alone could reach 920 GW by 2030 and potentially up to 1184 GW in a high scenario (Ember 2023b).

In the continued acceleration scenario, the additional solar and wind would be enough to displace all of the EU's coal-fired power generation by 2030. We have assumed that some fossil gas-fired power generation is displaced, such that coal falls from 17% to 2% of power generation over 2022–2030, and gas falls from 20% to 8% over the same period. As a result, power sector emissions fall from around 700 $MtCO_2$ in 2022 to 167 $MtCO_2$ by 2030 and 62 $MtCO_2$ by 2035.

Looking towards EVs, which are currently at around 20% of total passenger vehicle sales, a continuation of recent growth trends shows that they could reach a 51% share of sales by 2025, and an 92% share by 2030. We estimate that this would displace around 250 million barrels of oil demand per year by 2030, relative to a scenario with no EV uptake.

By 2030, the uptake of solar PV, wind and EVs under our continued acceleration scenario allows total fossil fuel demand in the EU to drop by 31% from 2022 levels.

Table 2: Details at country, regional and global level for the continued acceleration scenario.

Country	Wind and solar capacity in 2025 / 2030 (GW)	Growth in wind and solar capacity by 2030, from 2022 levels	Share of fossil fuel power generation in 2025 / 2030	Total change in fossil fuel demand by 2030 vs. 2022	Reduction in emissions in 2030 from STEPS ($MtCO_2$)
Brazil	83 / 150	x 3.1	3% / 0%	–7%	–36
China	1500 / 3400	x 4.3	53% / 38%	–13%	–615
EU	680 / 990	x 2.5	17% / 10%	–31%	–91
India	220 / 460	x 3.8	65% / 52%	+18%	–167
United States	500 / 910	x 3.2	44% / 31%	–24%	–297
Africa	45 / 130	x 6.5	67% / 57%	+6%	–23
Middle East	22 / 106	x 11.3	90% / 82%	+10%	-36
Central and Latin America (excl. Brazil)	60 / 150	x 6.3	28% / 8%	–10%	–118
Southeast Asia	86 / 340	x 9.9	66% / 42%	–1%	–418
Rest of World	510 / 950	x 3.1	47% / 31%	–15%	–367
World Total	3700 / 7600	x 3.7	53% / 36%	–10%	–2169

USA

As the second largest emitter globally, the US can significantly impact when global emissions peak. While emissions in the US have declined overall since the mid-2000s, there are still significant opportunities for deeper and faster reductions that can contribute to peaking global emissions.

In 2022, renewable generation surpassed coal and nuclear for the first time in the US power sector. Deployment of renewables is expected to ramp up going forward with the adoption of the Inflation Reduction Act in August 2022, as industry responds to new measures, such as investment and production tax credits (The White House 2023). The US EIA projects wind and solar PV capacity will increase from 281 GW in 2022 to just over 350 GW in 2025 and about 640 GW in 2030 (US EIA 2023).

Under our continued acceleration scenario, wind and solar deployment happens even faster, reaching just under 500 GW of installed capacity by 2025 and 910 GW by 2030. To reach these higher levels, wind and solar capacity ramps up immediately, reaching an average of around 70 GW in annual additions in 2023 and 2024. This is broadly consistent with estimates of the amount of utility scale wind and solar that could be deployed as a result of the Inflation Reduction Act (Jenkins *et al* 2022).

Wind and solar together make up 44% of total power generation in the continued acceleration scenario in 2030, and 64% in 2035. Coal is phased out by 2030, and fossil gas-fired generation is reduced by 64% by 2035. A higher uptake of renewables and greater reductions in fossil gas would be needed to meet the Biden administration's goal of a carbon-free power sector by 2035 (The White House 2021).

Significant emission reductions can also be achieved in the transport sector through the shift to EVs. Many projections show the US is on track to meet its target of 50% EV sales by 2030, our scenario shows this target could be achieved three years earlier (Anon 2022, IEA 2023d). Under this scenario, the sale of EVs increases to over a quarter of car sales by 2025 and to over 80% by 2030, compared to just 8% in 2022.

This would result in over 600 million barrels of oil being displaced, relative to a scenario with no EV uptake. A new rule proposed by the US Environmental Protection Agency to set stringent tailpipe pollution limits is expected to increase EV sales to 54-60% by 2030 (Davenport 2023, U.S. Environmental Protection Agency 2023).

The displacement of fossil fuels from the increase of wind, solar and EVs in the continued acceleration scenario would reduce fossil fuel demand in the US by 24% in 2030 compared to 2022 levels.

Brazil

Renewables already make up over 85% of Brazil's power generation, but most of this is hydro. Wind and solar are growing rapidly though: having made up less than 1% of generation in 2012, their share climbed to 16% in 2022 (Ember 2023a). In our continued acceleration scenario, their contribution continues to grow rapidly, reaching 27% by 2025 and 44% by 2030, with total capacity tripling between 2022 and 2030.

This growth allows coal, gas and oil to be displaced in Brazil's power system. These do not make up a large share of electricity generation – with current shares in 2022 of 2%, 7% and 2% respectively (Ember 2023a) – but the Brazilian government has emphasised its interest in expanding fossil gas power generation.

Our scenario shows that this is not necessary, as the growth in solar and wind allows a phase-out of coal by 2025, and gas by 2027, even when factoring in growing electricity demand. As a result, total fossil fuel demand in Brazil falls by 7% between 2022 and 2030.

The roll of different levers in achieving global peaking

Our analysis has identified range of levers which could be used to ensure that global emissions peak before 2025. These do not represent all possible levers – with several other important options on the table, including the roll out of heat pumps, improvements in energy efficiency gains, and more. Furthermore, the combinations of levers provided in our three scenarios are not the only combinations that are possible. What these scenarios show is that even when looking at a subset of possible options, it is clear that peaking before 2025 is achievable.

Figure 9A shows how each lever contributes to achieving a reduction in emissions in 2024 relative to 2023 in the continued acceleration scenario. It distinguishes between the contributions to reducing non-CO_2 emissions, via partial implementation of the global methane pledge and increased action to cut N_2O and F-gas emissions, and contributions to cutting CO_2 emissions from continued growth in EVs and wind and solar.

It also shows the potential impact if action to cut land-use emissions and enhance anthropogenic land-use sinks continues in line with the past ten years (see Box 2 for more discussion of LULUCF emissions). The threshold for peaking set out in Box 1 is also shown.

Figure 9B breaks down the emissions savings from the continued acceleration of EVs, wind and solar into the different fossil fuels displaced, and the regions in which fossil fuel displacement occurs. This shows that key to peaking GHG emissions in 2023 is an accelerated phase out of coal-fired power generation, driven by wind and solar deployment. Coal is displaced across the world, but our analysis highlights a particularly large potential in China, because wind and solar are growing so rapidly in the country.

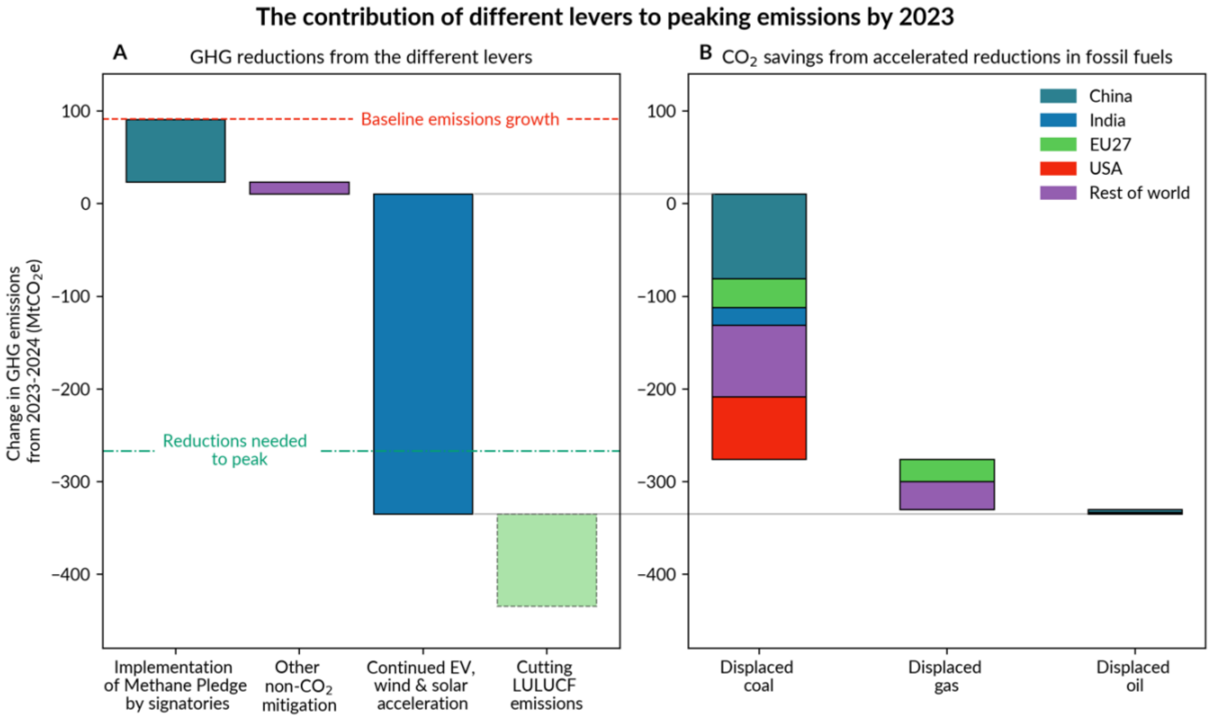

Figure 9: Contribution of each of the levers we assess to cutting emissions in 2024 relative to 2023.
We include cuts in land use change emissions, although these are not incorporated into our scenarios due to high uncertainties in both current and future emissions from land use change (see Box 2).

These contributions are all on top of the changes projected in the IEA's STEPS scenario. Where there is a relatively smaller contribution, this can be because the STEPS already assumes a strong growth in wind, solar and EVs. Larger contributions highlight where our analysis suggests the STEPS could accelerate.

Figure 9A shows that not all levers are technically necessary to achieve peaking in 2023. In fact, a continued acceleration of the roll out of wind, solar and EVs would be sufficient to peak emissions in 2023 with a 65% likelihood (almost exactly meeting our 66% peaking threshold, see Annex II: Methods) even without additional measures to mitigate non-CO_2 emissions.

All levers are important for maximising the likelihood that emissions would truly decline, even after accounting for interannual variation. And measures to cut non-CO_2 emissions – many of which are very low cost – are essential for limiting warming to 1.5°C. As the next section outlines, accelerated action across all sectors will be necessary to keep the Paris Agreement's temperature goal in reach.

Box 2: Reducing LULUCF emissions can help achieve a peak before 2025

Emissions from land-use, land-use change and forestry (LULUCF) currently represent roughly 10% of global emissions. However, LULUCF emissions are highly uncertain, with different methods for estimating them often providing very different levels and trends of emissions. At the same time, reductions in LULUCF emissions are easily reversible, particularly if increasing climate impacts such as wildfires lead to increased loss of carbon from the land-system.

For these reasons, we do not rely on progress in LULUCF emissions to help achieve peaking before 2025. None of the three scenarios introduced assume any progress in LULUCF emissions, which instead remain at the 2021 average level.

However, action to rapidly cut LULUCF emissions is possible. Reducing deforestation rates, restoring peatlands and wetlands, and increasing afforestation rates (with the right trees in the right places) and more could help achieve a peak in total greenhouse gas emissions before 2025.

Estimates of LULUCF emissions from the Global Carbon Project indicate that LULUCF emissions may be gently declining (although with very limited confidence in the trend). We explore what would happen if action to reduce and reverse deforestation and other land-use measures were implemented so that LULUCF emissions decline from 2023 onwards following the trend from the last 10 years. The results are shown in Figure 10. This shows that LULUCF emissions would fall ~100 $MtCO_2$ from 2023 to 2024 if the long-term trend is continued.

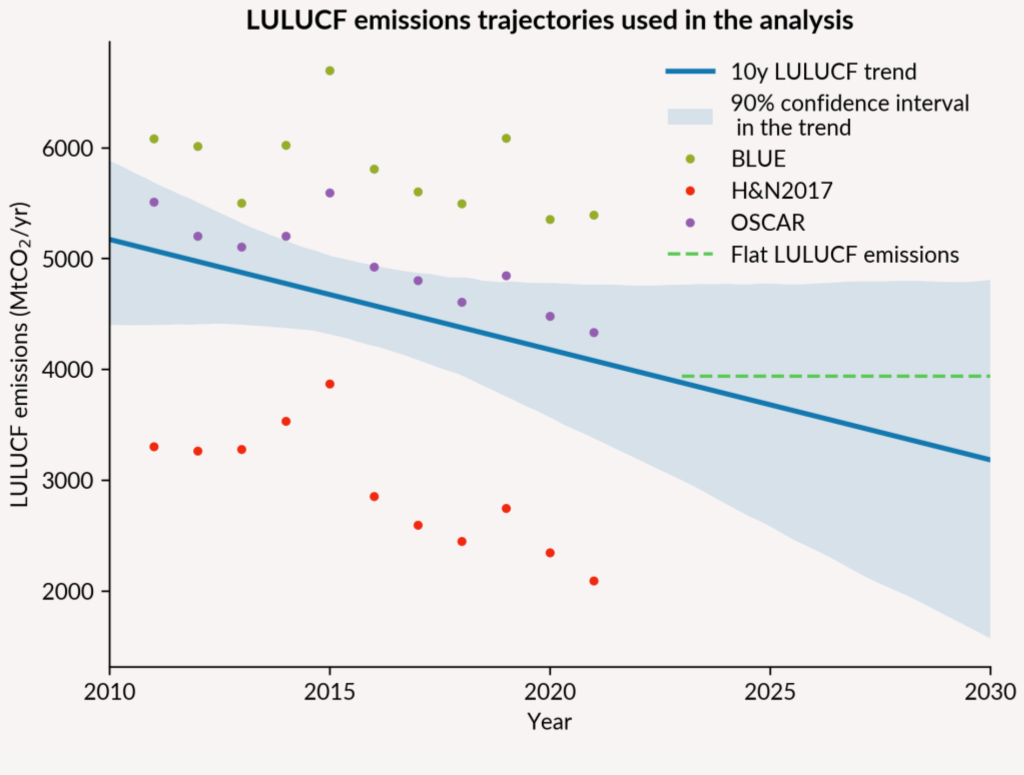

Figure B2: LULUCF emission trajectories

This illustrative analysis demonstrates that there is potential for emissions reductions from the land-use sector to contribute towards peaking. However, to truly quantify the potential for LULUCF action to contribute towards peaking, a more granular analysis would be required. And any possible reduction in emissions would be highly uncertain, given the large-scale year-to-year variability in LULUCF emissions. We therefore do not include LULUCF as a key lever in our scenarios.

Routes to keep 1.5°C in reach

This report focuses on what is possible in the very near-term to peak global emissions before 2025 and does not explicitly analyse what is needed for 1.5°C out to 2030 and beyond. What we can see from our scenarios is that emissions could fall a significant degree by 2030 through expansion of wind, solar and EV deployment following recent growth rates, and with moderate action to curb non-CO_2 emissions.

Even without further structural changes across other parts of the economy, global emissions could fall to under 50 $GtCO_2e$ by 2030 – a decline of 10% from estimated 2023 levels. While a 10% decline is a start, it is far from the halving of emissions needed across the decade to limit warming to 1.5°C (Climate Analytics 2023). Peaking emissions is just the start of the journey.

Figure 10 compares the continued acceleration scenario in this report to the IEA's latest Net Zero Emissions (NZE) scenario, as well as to the current STEPS scenario. This shows that, while our scenario cuts emissions faster than STEPS and sees emissions peak and begin to decline, that it is far from aligning with the IEA's NZE.

By 2030, fossil CO_2 emissions in the NZE fall to 24 $GtCO_2$. In the continued acceleration scenario, emissions only get down to 33 $GtCO_2$ by this time. Coal, gas and oil demand fall 45%, 11% and 12% over the decade in the NZE, while in the continued acceleration scenario, coal and gas demand fall by only 26% and 2%, while oil demand, although it has peaked, is still 2% above 2022 levels. Finally, in 2030, solar and wind capacity approaches 9 TW in the NZE, while it reaches 7.5 TW in the continued acceleration scenario.

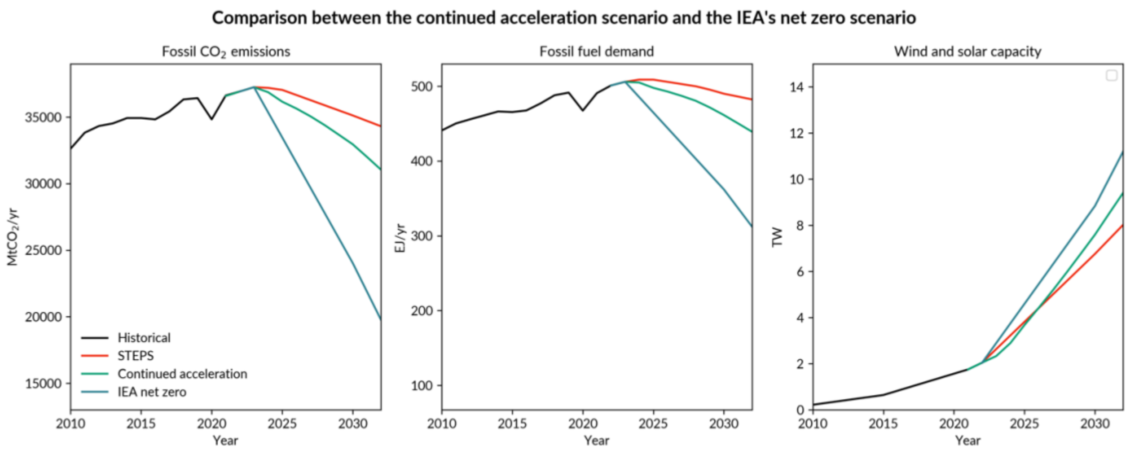

Figure 10: Comparison of the continued acceleration scenario and the IEA NZE.

While the continued acceleration scenario does not do enough limit warming to 1.5°C, this does not mean that 1.5°C is out of reach. This scenario is still relatively cautious in the level of change that it foresees later in the decade: it only boosts wind, solar and EV deployment based on an analysis of current growth trends, which could be further accelerated by additional policy interventions. It also assumes relatively moderate action to cut non-CO_2 emissions, and factors in very little additional action outside of the power sector.

To halve emissions by 2030, additional efforts would be required across the economy. This would include even greater roll out of renewables in the power sector, coupled with accelerated action to electrify end-use sectors and improve energy efficiency, as well as greater action to curb non-CO_2 emissions and reduce emissions from the land-use sector. These measures would allow fossil fuel demand to fall by the 40% needed over this decade to align with 1.5°C (Climate Analytics 2023).

In the NZE, the share of electrification in final energy consumption grows by eight percentage points from now until 2030, compared to just two percentage points in the STEPS, while the pace of energy efficiency improvements doubles to 4% per year. As a result, energy demand falls by 1.2% per year to 2030 in the NZE – whereas the STEPS (and our scenarios) see a growth by 0.7% per year. The IEA NZE also highlights the considerable room available for cheaply cutting energy sector methane emissions – by 75% by 2030.

The good news is that these changes are still possible, and some of them are already occurring today. For example, heat pump sales are rocketing in key markets (Rosenow *et al* 2022), while the rate of acceleration in wind and solar deployment over 2022–2023, if maintained, would put us on track for 1.5 TW/y of wind and solar deployment by 2030 (Climate Analytics 2023).

But while the technologies are there, the money is not yet flowing where it needs to at the necessary scale. According to the International Renewable Energy Agency (IRENA), investments in renewables need to rise from US $486 billion in 2022 to US $1300 billion by 2030 – more than a 2.5-fold increase (IRENA 2023b). The IEA's NZE provides estimates for clean energy as a whole of US $4.3 trillion per year by 2030, which is also around 2.5 times higher than 2023 levels (IEA 2023c).

The biggest increase is needed in emerging market and developing economies, which see a five-fold increase in clean energy spending from today's level under the NZE. Looking at total mitigation investment needs, the IPCC found that developing countries will need a four- to seven-fold increase from average levels over 2017-2020 (IPCC 2023).

Unlocking financial flows in the right places remains the biggest hurdle to keeping 1.5°C in reach, even though there is abundant evidence that the costs of getting on such a pathway are much less than the costs of failing to do so.

Conclusions

The world has known about the causes, impacts and dangers of climate change for many decades now. And yet greenhouse gas emissions have continued to rise, with the world putting its foot on the accelerator of the fossil fuel economy.

To limit warming to 1.5°C, we need to reduce CO_2 emissions to zero by mid-century. But before we do this, we need to stop emissions rising in the first place. This is why peaking is such an important milestone – it marks the beginning of the road towards a zero emissions future.

The IPCC has highlighted that peaking emissions before 2025 represents our best chance of limiting warming to 1.5°C. The good news is that this milestone is eminently achievable. Out of the three scenarios we produce, two of them achieve peaking by 2025.

The 'low effort' scenario peaks global greenhouse gas emissions in 2025, but does not manage to do so beforehand. The 'continued acceleration' scenario peaks emissions in 2023, with a ~70% chance that emissions would decline in 2024 once interannual variation in greenhouse gas emissions is accounted for.

Peaking emissions in 2023 depends on action over the coming months to support renewables deployment, cut methane emissions and more. In particular, action to curb fossil fuel use over 2024 and 2025 will be crucial to achieving peaking before 2025 and putting global emissions on a clear and long-term downward trajectory.

A global commitment to peak emissions before 2025 could help operationalise and bring into concrete focus the equally important, but longer-term tasks of slashing methane emissions, tripling renewables, doubling energy efficiency, and reducing fossil fuel use by 40% by 2030.

The continued acceleration of wind and solar uptake in major economies such as China, the EU27, India and the USA is central to achieving a peak in global emissions before 2025. This requires going beyond current policies but would be achieved if renewables continue to scale up the S-curve.

Our scenario looks at what can be achieved based on current trends – it is not a target or ambition ceiling. Renewables could grow even faster than our S-curve predicts, particularly if a commitment to triple renewable capacity by 2030 is not only made at COP28 but translated into concrete action on the ground. This would help close the gap to 1.5°C further.

As wind and solar deployment grows across the world, approaching peak fossil fuel demand is inevitable. We find that coal demand could peak in 2023 and start falling fast, with coal demand almost halved by 2035 relative to today's levels. Gas demand would peak in 2024 and oil demand in 2025, marking the end of decades of demand growth. Again, while peaking fossil fuel demand would be the start, it is not the end. To meet our climate goals, we would need to see an equitable and rapid phase out of fossil fuels.

The world can peak global emissions before 2025, but this is not guaranteed. Current NDCs collectively fall far short of the mark, adding up to only a 2% reduction by 2030 compared to 2019 levels (UNFCCC 2023). And existing fossil fuel production plans, if realised, would push the world into very dangerous territory.

Yet, momentum behind the energy transition is building, and if governments get behind rather than push against this, it will be possible to meet a key IPCC milestone for keeping the 1.5°C limit in reach.

COP28 is an opportunity for the world to respond directly to what the latest science shows is needed: a global peaking before 2025, on the road to a tripling of renewables, a doubling of energy efficiency improvement rates, and a 40% cut in fossil fuels by 2030.

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Annex I: Drivers of peaking

In this report, we identify a growing number of countries which have already peaked their emissions and are now in the phase of declining emissions. To do this, we first construct a dataset of national-level GHG emissions, territorial fossil CO_2 emissions and consumption-based fossil CO_2 emissions. The data sources used to construct these time-series are highlighted in Table 3.

Table 3: Data sources used to construct national emissions trajectories.

Variable	Sources used
Total GHG emissions	PRIMAP (Gütschow and Pflüger 2023) for non-LULUCF emissions, national inventories for LULUCF (Grassi *et al* 2022).
Territorial fossil CO_2 emissions	PRIM AP (Gütschow and Pflüger 2023).
Consumption-based fossil CO_2 emissions	Global Carbon Budget (Friedlingstein *et al* 2022).

We identify a set of 20 countries that have peaked fossil CO_2 emissions over the 15-year period of 2006-2021. Of these, 14 of them have sufficient data for us to run a Kaya decomposition analysis. This allows us to understand the underlying drivers of falling CO_2 emissions in these countries. To do this we split fossil CO_2 into five underlying drivers, which are shown in the following equation:

$$CO_2 = GDP * \frac{Final\ Energy}{GDP} * \frac{Final\ Energy_{fossil}}{Final\ Energy} * \frac{Final\ Energy_{fossil}}{Primary\ Energy_{fossil}} * \frac{Fossil\ CO_2}{Primary\ Energy_{fossil}}$$

$$CO_2 = GDP * \ Energy\_intensity \ * Fossil\_fraction \ * Fossil\_efficiency \ * Carbon\_intensity$$

$$C = \ C_{GDP} * \ C_{Energy\_intensity} \ * C_{Fossil\_fraction} * C_{Fossil\_Efficiency} * C_{Carbon\_intensity}$$

This equation describes CO_2 emissions as driven by:

- The size of the economy (*GDP*)
- The energy intensity of the economy (*energy_intensity*). This refers to how much energy is required to sustain a unit of economic output. Falling energy intensity could be due to uptake of energy efficiency measures, or structural change in the economy (e.g. away from intensive manufacturing and towards a service-based economy).
- The share of fossil fuels in the energy mix (*fossil_fraction*).
- The efficiency with which fossil fuels are converted from primary energy to energy for the end-users (*fossil_efficiency*). This refers to losses in the upstream energy system – for example converting coal to electricity involves over half of the energy being lost as waste heat.
- The carbon intensity of the fossil fuels used (*carbon_intensity*). Falling carbon intensity could be driven by a fuel-switching from coal to gas. However, while this switch could potentially lower immediate CO_2 emissions, fossil gas is still a dirty and polluting fossil fuel which would need to be phased out in 1.5°C compatible pathways.

We then use the LMDI technique (Ang 2005) to decompose changes in fossil CO_2 emissions over a period of t_1 to t_2 into the five underlying drivers, using the following equation:

$$\Delta C = \Delta C_{GDP} + \Delta C_{Energy\_intensity} + \Delta C_{Fossil\_fraction} + \Delta C_{Fossil\_Efficiency} + \Delta C_{Carbon\_intensity}$$

Where:

$$\Delta C_X = \frac{C^{t_2} - C^{t_1}}{\ln C^{t_2} - \ln C^{t_1}} \ln\left(\frac{C_X^{t_2}}{C_X^{t_1}}\right)$$

To conduct this analysis, we use energy data from the IEA World Energy Balances and GDP data from the World Bank.

Figure 11 shows the results of the analysis. It shows that in the past, the key driver of emissions reductions has been improvements in the energy intensity of the economy. This contributed, in the median, over 75% of the reduction in fossil CO_2 over the period.[5] Improvements in energy intensity have largely compensated for the effect of

[5] As GDP growth generally contributes negatively to falling emissions (i.e. drives emissions growth), then some of the contributions to falling emissions can approach or exceed 100%, as they are compensating for the influence of GDP growth on emissions.

GDP growth, leading to falling total energy demand in most of the countries (13 out of 14) that have reduced emissions.

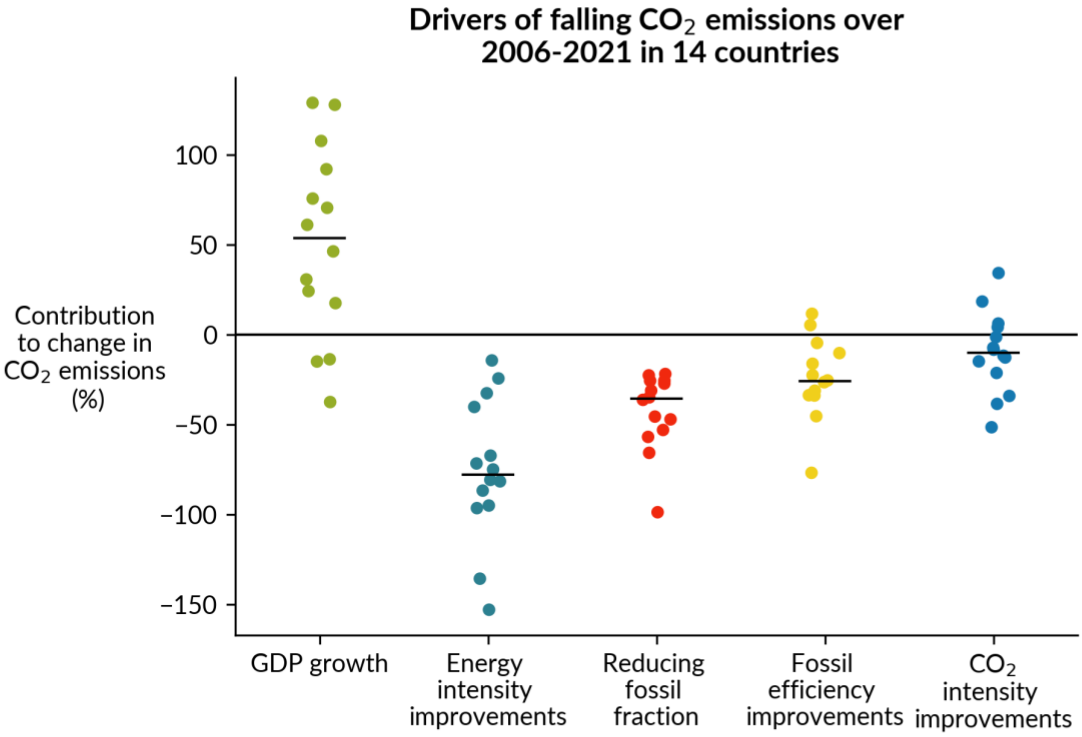

Figure 11: Drivers of declining fossil CO_2 emissions in countries which have peaked historically. Each dot represents an individual country, with the median represented by the horizontal line.

Reductions in the share of fossil fuels in the energy mix have also contributed to emissions reductions. The median contribution was equivalent to 35% of the overall reduction in fossil CO_2 over the period in the median. Improvements in the upstream efficiency of converting fossil fuels dug from the ground into energy for the end-user, and improvements in the carbon intensity of fossil energy have played a more minor role in reducing emissions.

Table 4 summarises the relative impact of each driver in reducing emissions over the past decade.

Table 4: Drivers of declining fossil CO_2 emissions in countries which have peaked historically. The table shows the median contribution of each factor to emissions reductions over the 2006-2021 period. The interquartile range is shown in brackets. While for any countries, the sum of the five drivers is 1, the medians across all countries do not necessarily sum to 1.

Variable	GDP	Energy intensity	Fossil fraction	Fossil efficiency	Carbon intensity
Relative contribution to declining fossil CO_2 emissions	−54% (−19% to −88%)	78% (47% to 93%)	35% (26% to 51%)	26% (12% to 33%)	10% (−3% to 20%)

While some broad patterns across countries can be identified, there is also considerable variation in the drivers of emissions reductions across countries. For example, Sweden, Finland, and Denmark have seen falling CO_2 emissions driven predominantly by reducing the fossil fraction (responsible for ~75% of emissions reductions), with energy intensity improvements having a smaller role (responsible for ~50% of emissions reductions).

Meanwhile in the USA and Belgium, carbon intensity improvements have provided a larger contribution to declining emissions, as switching away from coal and towards fossil gas reduced the carbon intensity of fossil energy in the country.

Historical peaking has been largely driven by improvements in energy intensity, with more limited action to truly reduce the share of fossil fuels in the energy mix. But going forwards, can the same pattern as the past be applied to the future? We also apply this decomposition analysis to explore the drivers of emissions reductions in 1.5°C compatible pathways over the next fifteen years, using the IPCC's AR6 ensemble (Byers *et al* 2022) and filtering to avoid unsustainable CDR deployment (Climate Analytics 2023).

The results show that energy intensity improvements remain essential, but displacing fossil fuels and replacing them with renewables becomes even more important in driving emissions reductions over the next 15 years. This is made possible because of the significant cost declines and capacity build-outs in solar, wind, batteries and other clean energy technologies that have taken place in recent years.

Our analysis of possible routes to achieving a peak in emissions before 2025 confirms that cutting the share of fossil fuel use in the energy system can already have a big impact on global emissions in the next two years. Adding in the potential for further reducing the energy intensity of the global economy – which we have not explored – would yield even greater emissions declines and close the gap to a 1.5°C pathway.

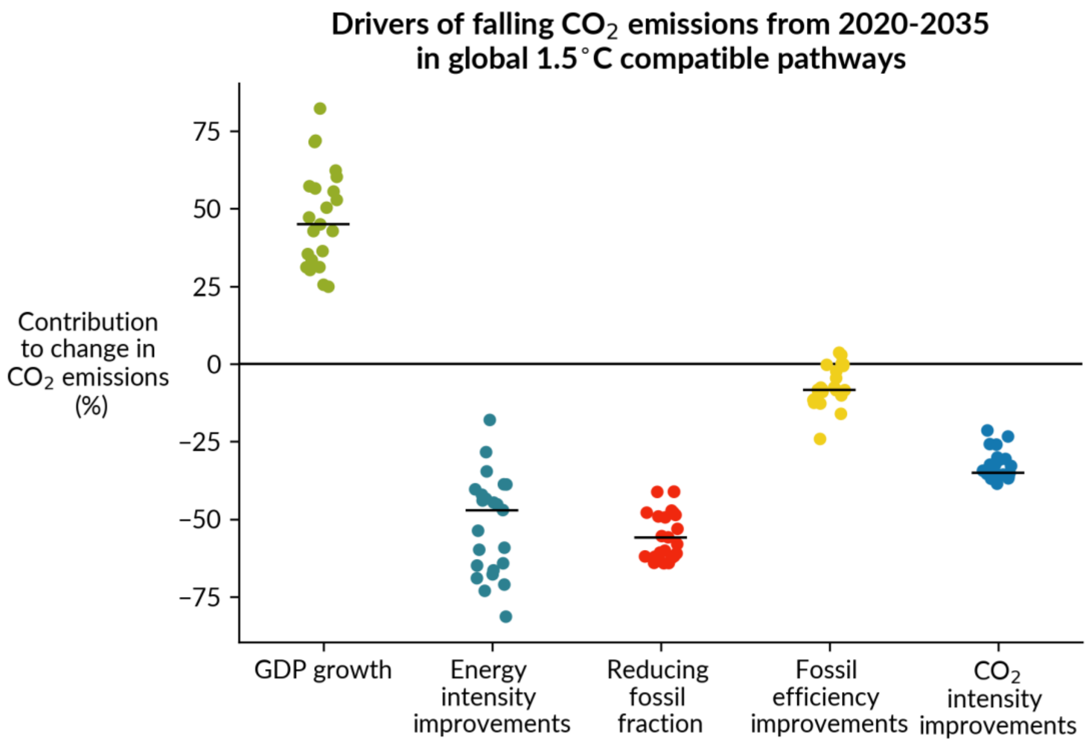

Figure 12: Drivers of falling CO_2 emissions in 1.5°C compatible pathways from the IPCC's AR6 report, filtered to meet sustainability criteria.

Annex II: Methods

Modelling future greenhouse gas emissions

In this work we develop three scenarios to explore how global GHG emissions could respond to clean energy technology uptake and other mitigation actions, to achieve a peaking in the 2020s.

Table **1** in the main report summarises the key features of each scenario. In this section we provide further detail on how the scenarios are produced, focusing in turn on fossil CO_2 emissions, non-CO_2 emissions and land-use CO_2 emissions.

Selecting levers for analysis

There are a wide range of levers which could be pulled to slow the growth of GHG emissions and put them into long-term decline, achieving peaking. To be relevant on the timescale of peaking, levers must be implementable in a short period of time (within the next ~24 months). This excludes some longer-term levers which could play a significant role in reducing emissions by 2030 and beyond, such as some zero-carbon technologies in industry.

Levers that could be implemented within the IPCC peaking timescale include supporting the continued deployment of rapidly diffusing zero-carbon technologies (such as wind and solar, EVs and heat pumps), action to reduce energy demand by energy efficiency improvements and behavioural shifts, action to cut non-CO_2 emissions (particularly from F-gases and methane), and action to reduce and reverse deforestation and land degradation. All of these levers have either:

A) Already impacted the energy system noticeably in recent years, highlighting their ability to influence the near-term trajectory of emissions. For example, fossil fuel demand in Europe has fallen in recent years due to rapid wind and solar rollout, coupled with heat pump deployment and actions to reduce heating demand in buildings.

B) Historically shown that they can rapidly influence global greenhouse gas emissions. For example, Brazilian land-use emissions peaked and fell rapidly through the 2000s as action to curb deforestation was implemented by the Lula administration. If similar action is taken again, then land-use emissions could decline significantly over a short timeframe.

C) Have been shown to be low-regrets options that can be taken up rapidly. For example, the IEA has highlighted the abundance of options to cut methane emissions from the energy sector by up to 75% in 2030.

From these, we then focus on three main levers: action to curb non-CO_2 emissions (particularly F-gases and methane), continued deployment of wind and solar along current growth trends, and continued deployment of EVs along current growth trends. The selection of these three levers is driven by data availability, and does not represent a judgement on the relative importance of these levers compared to other options for cutting emissions in the near-term.

Fossil CO_2 emissions

Our starting point for estimating future CO_2 emissions from fossil fuels and industrial processes (FFI) is the IEA STEPS scenario. This attempts to understand how the global energy system would evolve under today's policy settings. The STEPS scenario is used to project fossil CO_2 emissions in our baseline and low effort scenarios, while a further accelerated variant of STEPS is used for the continued acceleration scenario.

Under the latest STEPS scenario, released in October 2023, the IEA shows that fossil CO_2 emissions could peak before 2025 – and even as soon as 2023 – before entering long-term structural decline later this decade. 2023 could represent the high point of global fossil CO_2 emissions that will never be equalled again.

This peak in fossil CO_2 emissions is driven by a peak in demand for fossil fuels. In the latest STEPS scenario, coal demand peaks in 2022, while oil and gas demand peak in 2028/2029 respectively.

However, while fossil CO_2 emissions could peak in 2023 according to the IEA, the pace of reductions post-peaking is relatively small. By 2030, fossil CO_2 emissions are still above 35 $GtCO_2e/yr$ — above 2010 levels and only down 6% from the 2023 peak.

STEPS attempts to capture the current rate of change in the energy system. But there is an open question about how well it achieves this. Historically, the STEPS scenario has not sufficiently captured the pace of change in rapidly diffusing technologies such as wind and solar, and its projections have been revised upward each year. Other lines of evidence suggest that the inherent momentum towards zero-carbon technology could be larger than suggested by STEPS, and that fossil fuel emissions could start falling faster (Nijsse *et al* 2023, RMI 2023b).

We therefore produce a scenario which explores how fossil fuel demand could peak sooner and fall faster, if key zero-carbon technologies continue to grow along current technology trends. To construct our continued acceleration scenario, we focus on wind, solar and electric cars, three zero-carbon technologies which have been undergoing explosive deployment growth.

There are many ways to model the future deployment of rapidly diffusing technologies, but in this report, we use an S-curve approach. Historical technological transitions and innovation theory show that technology deployment rarely follows a straight line, but often follows an S-curve. In an S-curve, deployment of new technologies starts slow, but reaches a tipping point where they transition into a period of rapid, explosive growth, before eventually plateauing as the technology saturates the market.

For solar PV, wind turbines and electric vehicles, we fit S-curves to the historical data to understand how deployment could grow in the coming years, if these technologies continue to scale up the S-curve. We apply these S-curves at the regional and country-level, rather than the global level, because recent growth rates have varied substantially across the world. In the case of the EU, US and India, we accelerate the ambition of the S-curves used further, as there are already country-level targets that exceed the levels reached by the S-curves.

We then compare these country-level S-curves to the IEA's STEPS policy. Where the S-curves are more ambitious than the STEPS scenario, we use them instead of the STEPS scenario, and calculate the additional emissions savings that would occur. This produces an accelerated STEPS scenario which better accounts for the real-world pace of the energy transition.

Non-CO_2 emissions

We build three possible scenarios for non-CO_2 emissions, which are used for each of our three global scenarios.

In the baseline scenario, we assume that methane, nitrous oxide and F-gases continue on the 2012-2022 trend, using PRIMAP data to quantify this (Gütschow and Pflüger 2023). We use the data in PRIMAP from third parties, rather than direct country reports, as this tracks more closely with other global emissions data sources such as EDGAR (Crippa *et al* 2023). In this scenario, non-CO_2 emissions continue to grow strongly over the decade, with no or limited action taken to reduce them.

In the low effort scenario, we model the impact of taking limited action to cut non-CO_2 emissions. For methane and nitrous oxide, we calculate how far emissions could be cut if no-regrets abatement options (defined as those with a mitigation cost of < 0 \$/tCO_2e) are taken up out to 2030. To calculate this we use data from the Environmental Protection Agency (EPA 2019). For F-gases, we model the implementation of the Kigali Amendment to the Montreal Protocol. This amendment covers HFCs, which represent around 85% of global F-gas emissions. Implementation of the Kigali Amendment could lead to HFC emissions falling 15% across the 2020s (Purohit *et al* 2022). We then assume that non-HFC F-gases continue their 2012-2022 decadal trend.

In the continued acceleration scenario, the assumptions for N_2O and F-gases are the same as the low effort scenario, but we increase the level of emissions reductions for methane, by including implementation of the global methane pledge by current signatories, which represent around 45% of global methane emissions (IEA 2022). This does not represent full implementation of the Global Methane Pledge – with methane emissions only falling 13% across the decade. However, it captures the potential for methane emissions to fall if current methane pledge signatories implement their commitments to cut emissions by 30% relative to 2020 levels.

To avoid an abrupt change in the development of non-CO_2 emissions, we model a gradual uptake of abatement across the 2023–2030 period. We apply a quadratic form to the emissions trajectory, which means that the rate of change in emissions grows linearly across the time-period, with the initial rate of change in 2022–2023 set by the historical growth rate in emissions over the 2012-2022 period.

Land-use emissions

Emissions from land-use, land-use change and forestry (LULUCF) are highly uncertain. Multiple different methods exist for estimating LULUCF emissions, including satellite–based measures, book–keeping models, dynamic global vegetation models or DGVMs, and the analysis conducted for national inventories. Often these different approaches come up with different overall emissions levels and trends (Friedlingstein *et al* 2022, Feng *et al* 2022).

Bookkeeping models calculate emissions using a combination of observation-based carbon density data and estimates of land-use and land-use change over time (Hartung *et al* 2021). These provide different results compared to the land-use change emissions included in governments' national inventories, because of differences in methods and definitions used to determine which emissions and removals are truly human-induced (Grassi *et al* 2021).

Book-keeping models and DGVMs suggest that net LULUCF emissions have declined gently over the past decade, but with very limited confidence in the trend (Friedlingstein *et al* 2022). Meanwhile, LULUCF emissions from national inventories, when aggregated to the global level, suggest that the pace of LULUCF emissions reductions has slowed in the past 10 years or so, with wide year-on-year variation (Grassi *et al* 2022). Satellite observations of emissions from tropical forests suggest a growing trend in emissions (Feng *et al* 2022), which contrasts with the declining trend observed in the book-keeping models.

For these reasons, we take a conservative approach in our scenarios and assume that net LULUCF emissions plateau at current levels, taking the mean estimate from three bookkeeping models in 2021 and extrapolating this forwards (Friedlingstein *et al* 2022). This ensures that any achievement of peaking in the scenarios is not overly dependent on progress in cutting LULUCF emissions.

This is justified given the large uncertainty in LULUCF emissions, and also due to their highly varying nature. LULUCF emissions reductions and removals are highly vulnerable to reversals when changes in land-use or natural disturbances arise. Therefore, a peak which is overly dependent on progress in LULUCF emissions could well end up being a temporary peak, as a reversal in LULUCF emissions changes the direction of global emissions trajectories.

Deforestation is the main driver of emissions from LULUCF. Governments have pledged to end illegal deforestation – for example through the New York Declaration on Forests made in 2014 and the 2021 Glasgow Leaders' Declaration on Forests and Land Use – implying there is political will to tackle this issue. But while deforestation rates have been on the decline since a recent high in 2016, they rose again slightly from 2021 to 2022 (Boehm *et al* 2023).

If action to tackle deforestation and forest degradation is successful and future LULUCF emissions decline, this would improve our confidence of being able to peak emissions in the very near term and would lead to steeper reductions out to 2030.

Identifying countries which have peaked emissions and the drivers of peaking

Estimating interannual variation in emissions

Different approaches can be used to define what constitutes a peak in greenhouse gas emissions. In this report we use a statistical approach which acknowledges that in the real world, emissions vary from year-to-year driven by a range of factors, including geopolitical events, weather variations (e.g., those driven by El Niño), economic factors and more.

Greenhouse gas emission pathways produced by scenario modelling exercises are however smooth curves, which do not account for this interannual variation.

Conceptually, real-world emissions pathways can be conceived of as the combination of a smooth 'structural' component (the changes envisaged in the scenario), and some 'noise' which represents the interannual variation. In the real world of course, this inter-annual variation could actually impact on the changes envisaged in the scenario – just as Russia's illegal invasion of Ukraine has led to an acceleration of the energy transition in Europe. In our approach we determine whether the smooth rate of emissions reduction in a scenario is strong enough to overcome plausible interannual variation in GHG emissions from other factors which are not accounted for in the scenarios.

If year-on-year emissions reductions are given by the following equation:

$$E_{red} = Scenario_{red} + \delta_{IAV}$$

Where:

- E_{red} = emissions reductions in the real-world
- $Scenario_{red}$ = structural reduction in emissions in the scenario
- δ_{IAV} = Interannual variability

Then peaking is defined as when

$$(P(E_{red}) < 0) \geq 66\%$$

To quantify δ_{IAV}, we look at total GHG emissions over the last 50 years (1970–2019)[6], and calculate a probability density function for interannual variation in GHG emissions. This probability density function is shown in Figure B1, and is initially centred around the 50-year trend in emissions, of + 560 $MtCO_2e$ /yr.

We then assume that interannual variation in future GHG emissions can be represented by interannual variation in the past but centred around a new trendline. We calculate what the trendline would have to be in order for a certain proportion of the probability distribution (66% or 90%) to lie below the y-axis.

To produce the probability distribution, we use GHG emissions data from EDGAR (Crippa *et al* 2023), complemented with land-use change emissions from the mean of the three bookkeeping models in the Global Carbon Budget (Friedlingstein *et al* 2022).

We use EDGAR over PRIMAP here as sometimes PRIMAP fills in missing data years by linear interpolation – which led to a more uniform interannual variation than in EDGAR and a slightly narrower distribution. To take a precautionary approach and avoid underestimating interannual variation in GHGs, we therefore use EDGAR data.

However, a similar probability distribution and peaking threshold would be provided using PRIMAP data – with the peaking and strong declining thresholds being –260 $MtCO_2e$ /yr and –890 $MtCO_2e$ /yr respectively, rather than –267 $MtCO_2e$ /yr and –950 $MtCO_2e$ /yr.

We do not apply this interannual variation criteria to our definition of fossil fuel demand peaks. This is because interannual variation in fossil demand is generally lower than the variation in total greenhouse gas emissions (where variation in land-use change emissions is particularly large).

[6] We exclude 2020 and 2021 from the analysis to avoid including the 'dip and rebound' from the COVID pandemic in our estimation of interannual variation in GHG emissions. This is because the rebound in emissions in 2021 is not real interannual variation in emissions, but directly related to the dip in 2020. Including them would artificially broaden the probability distribution, suggesting that a +2 $GtCO_2e$ growth in a single year could happen without the preceding -2 $GtCO_2e$ downturn.

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