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No more hot air ... please!

With a massive gap between rhetoric and reality, countries draft new climate commitments

Emissions Gap Report 2024

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Glossary

This glossary is compiled drawing on glossaries and other resources available on the websites of the following organizations, networks and projects: the Intergovernmental Panel on Climate Change, United Nations Environment Programme, United Nations Framework Convention on Climate Change (UNFCCC) and World Resources Institute.

Anthropogenic emissions: Emissions derived from human activities.

Baseline/reference: The state against which change is measured. In the context of climate change transformation pathways, the term "baseline scenarios" refers to scenarios based on the assumption that no mitigation policies or measures will be implemented beyond those already in force and/or legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy efforts. Typically, baseline scenarios are compared to mitigation scenarios that are constructed to meet different goals for greenhouse gas (GHG) emissions, atmospheric concentrations or temperature change. The term "baseline scenario" is used interchangeably with "reference scenario" and "no-policy scenario".

Carbon dioxide emission budget (or carbon budget): For a given temperature rise limit, for example a 1.5°C or 2°C long-term limit, the corresponding carbon budget reflects the total amount of carbon emissions that can be emitted for temperatures to stay below that limit. Stated differently, a carbon budget is an area under a carbon dioxide (CO_2) emission trajectory that satisfies assumptions about limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise.

Carbon dioxide equivalent (CO_2e): A way to place emissions of various radiative forcing agents on a common footing by accounting for their effect on the climate. It describes, for a given mixture and amount of GHGs, the amount of CO_2 that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, unless otherwise specified, GHG emissions are the sum of the basket of GHGs listed in Annex A to the Kyoto Protocol, expressed as CO_2e, assuming a 100-year global warming potential.

Carbon dioxide removal (CDR): Refers to anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

Carbon neutrality: This is achieved when an actor's net contribution to global CO_2 emissions is zero. Any CO_2 emissions attributable to an actor's activities are fully compensated by CO_2 reductions or removals exclusively claimed by the actor, irrespective of the time period or the relative magnitude of emissions and removals involved.

Conditional nationally determined contribution: A nationally determined contribution (see below) proposed by some countries that is contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.

Conference of the Parties to the United Nations Framework Convention on Climate Change (COP): The supreme body of the UNFCCC. It currently meets once a year to review the UNFCCC's progress.

Emissions pathway: The trajectory of annual GHG emissions over time.

Global stocktake: The global stocktake was established under Article 14 of the Paris Agreement. It is a process for Member States and stakeholders to assess whether they are collectively making progress towards meeting the goals of the Paris Climate Change Agreement. The global stocktake assesses everything related to where the world stands on climate action and support, identifying the gaps, and working together to agree on solutions pathways, to 2030 and beyond. The first global stocktake takes place at COP 28 in 2023.

Global warming potential (GWP): An index representing the combined effect of the differing times GHGs remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation.

Greenhouse gases (GHGs): The atmospheric gases responsible for causing global warming and climatic change. The major GHGs are CO_2, methane (CH_4) and nitrous oxide (N_2O). Less prevalent but very powerful GHGs include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Integrated assessment models: Models that seek to combine knowledge from multiple disciplines in the form of equations and/or algorithms, in order to explore complex environmental problems. As such, they describe the full chain of climate change, from the production of GHGs to atmospheric responses. This necessarily includes relevant links and feedback between socioeconomic and biophysical processes.

Kyoto Protocol: An international agreement signed in 1997 and which came into force in 2005, standing on its own, and requiring separate ratification by Governments, but linked to the UNFCCC. The Kyoto Protocol, among other things, sets binding targets for the reduction of GHG emissions by industrialized countries.

Land use, land-use change and forestry (LULUCF): A GHG inventory sector that covers emissions and removals of GHGs resulting from direct human-induced LULUCF activities.

Least-cost pathway: Least-cost pathway scenarios identify the least expensive combination of mitigation options to fulfil a specific climate target. A least-cost scenario is based on the premise that, if an overarching climate objective is set, society wants to achieve this at the lowest possible cost over time. It also assumes that global actions start at the base year of model simulations (usually close to the current year) and are implemented following a cost-optimal (cost-efficient) sharing of the mitigation burden between current and future generations, depending on the social discount rate.

Likely chance: A likelihood greater than 66 per cent chance. Used in this assessment to convey the probabilities of meeting temperature limits.

Mitigation: In the context of climate change, mitigation relates to a human intervention to reduce the sources or enhance the sinks of GHGs. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of CO_2 from the atmosphere.

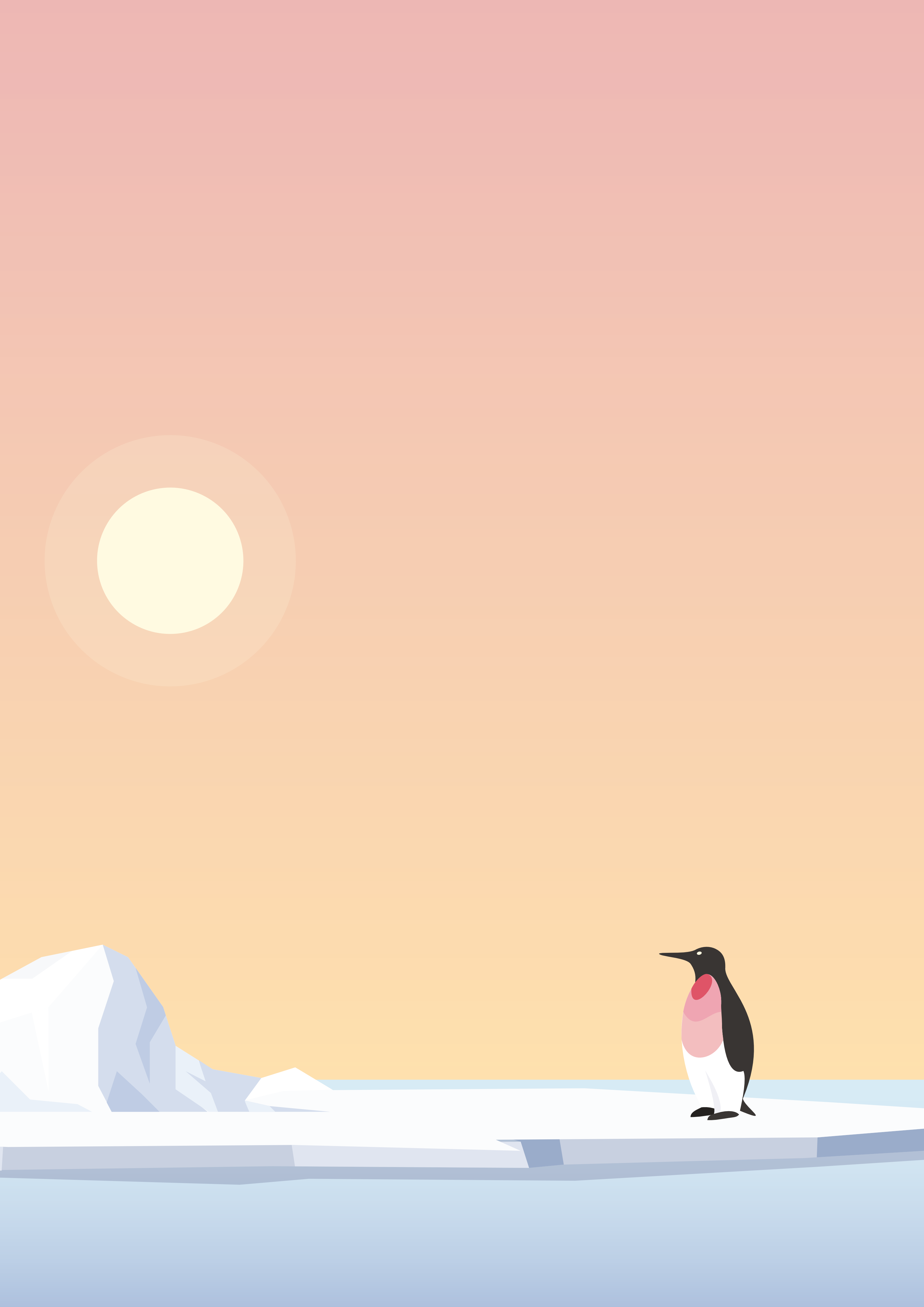
Mitigation potential: Mitigation potentials are the quantity of GHG emission reductions or removals that can be achieved by a given mitigation option in a specific period relative to specified emission baselines.

Nationally determined contribution (NDC): Submissions by countries that have ratified the Paris Agreement which present their national efforts to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. New or updated NDCs are to be submitted in 2020 and every five years thereafter. NDCs thus represent a country's current ambition or target for reducing emissions nationally.

Offset: In climate policy, a unit of CO_2e emissions that is reduced, avoided or sequestered to compensate for emissions occurring elsewhere.

Scenario: A description of how the future may unfold, based on "if-then" propositions. Scenarios typically include an initial socioeconomic situation and a description of the key driving forces and future changes in emissions, temperatures or other climate change-related variables.

Source: Any process, activity or mechanism that releases a GHG, an aerosol or a precursor of a GHG or aerosol into the atmosphere.



Contents

Foreword

Climate crunch time is here. As wildfires, heatwaves, storms and droughts intensify globally, nations are preparing new nationally determined contributions (NDCs) for submission early next year ahead of COP 30 in Brazil. Nations must accelerate action now, show a massive increase in ambition in the new pledges and then deliver urgently with policies and implementation. If they do not, the Paris Agreement target of holding global warming to 1.5°C will be dead within a few years and 2°C will take its place in the intensive care unit.

The 2024 edition of UNEP's Emissions Gap Report shows how much higher nations must aim. To get on a least-cost pathway for 1.5°C, emissions must fall 42 per cent by 2030, compared with 2019 levels. For 2°C, emissions must fall 28 per cent by 2030. Looking out to 2035 – the next milestone after 2030 to be included in NDC targets – emissions must fall 57 per cent for 1.5°C and 37 per cent for 2°C.

As greenhouse gas emissions rose to a new high of 57.1 gigatons of carbon dioxide equivalent in 2023, the cuts required from today are larger; 7.5 per cent must be shaved off emissions every year until 2035 for 1.5°C. Current promises are nowhere near these levels, putting us on track for best-case global warming of 2.6°C this century and necessitating future costly and large-scale removal of carbon dioxide from the atmosphere to bring down the overshoot.

However, this report shows that it remains at least technically possible to get on a 1.5°C pathway. Increased deployment of solar photovoltaic technologies and wind energy could deliver 27 per cent of the total emission reduction potential in 2030 and 38 per cent in 2035. Action on forests could deliver around 20 per cent of the potential in both years. Other strong options include efficiency measures, electrification and fuel switching in the buildings, transport and industry sectors.

To deliver, we would need a whole-of-government approach, measures that maximize socioeconomic and environmental co-benefits while reducing trade-offs, and a minimum sixfold increase in mitigation investment – backed by reform of the global financial architecture and strong private-sector action. G20 members, particularly the largest emitters, would need to do the heavy lifting, as they dominate the world economy.

Essentially, we would need global mobilization on a scale and pace never seen before. Many will say this is impossible. But to focus solely on whether it is possible misses one crucial point: the transformation to net-zero economies must happen, and the sooner this global transformation begins the better. Every fraction of a degree avoided counts in terms of lives saved, economies protected, damages avoided, biodiversity conserved and the ability to rapidly bring down any temperature overshoot.

So, I urge every nation: no more hot air, please. Use COP 29 in Baku, Azerbaijan to increase action now, set the stage for dramatically stronger NDCs, and then go all out to get on the 1.5°C pathway by 2030. The sooner we strike out hard for a low-carbon, sustainable and prosperous future, the sooner we will get there – which will save lives, save money and protect the planetary systems upon which we all depend.

Inger Andersen
Executive Director
United Nations Environment Programme

Executive summary

All eyes on the next nationally determined contributions

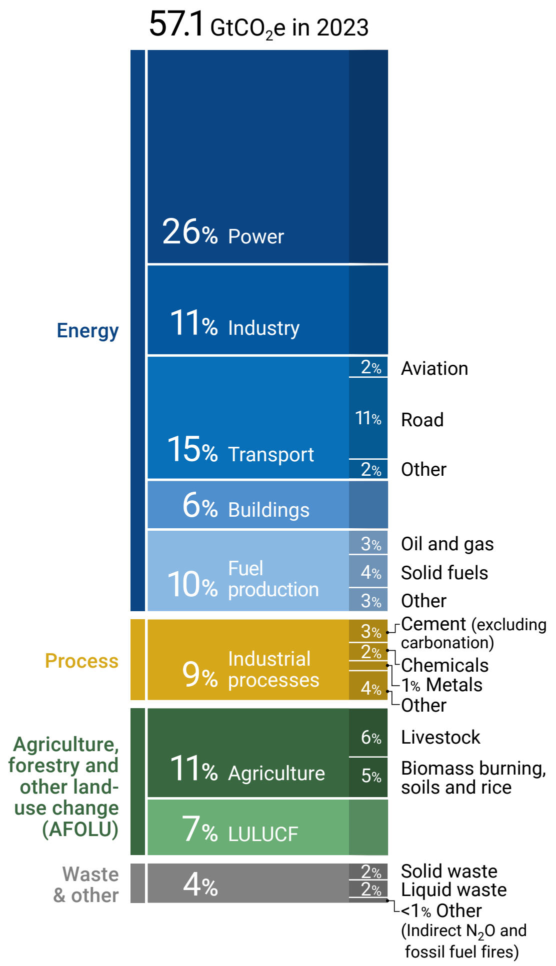
The deadline for countries to submit their next nationally determined contributions (NDCs) with mitigation targets for 2035 is only a few months away, at the time of writing. The fifteenth Emissions Gap Report has a special focus on what is required from these NDCs to maintain the possibility of achieving the long-term temperature goal of the Paris Agreement of limiting global warming to well below 2°C, while pursuing 1.5°C relative to pre-industrial levels. Its core message is that ambition means nothing without action – unless global emissions in 2030 are brought below the levels implied by existing policies and current NDCs, it will become impossible to reach a pathway that would limit global warming to 1.5°C with no or limited overshoot (>50 per cent chance), and strongly increase the challenge of limiting warming to 2°C (>66 per cent chance). The next NDCs must deliver a quantum leap in ambition in tandem with accelerated mitigation action in this decade.

The magnitude of the challenge is indisputable. At the same time, there are abundant opportunities for accelerating mitigation action alongside achieving pressing development needs and Sustainable Development Goals. Technology developments, particularly in wind and solar energy, continue to exceed expectations, lowering deployment costs and driving their market expansion. The updated assessment of sectoral emission reduction potentials included in this year's report shows that the techno-economic emission reduction potential based on existing technologies and at costs below US$200 per ton of carbon dioxide equivalent (tCO_2e) remains sufficient to bridge the emissions gap in 2030 and 2035. But this will require overcoming formidable policy, governance, institutional and technical barriers as well as an unprecedented increase in the support provided to developing countries along with a redesigning of the international financial architecture.

1. Global greenhouse gas emissions set a new record of 57.1 $GtCO_2e$ in 2023, a 1.3 per cent increase from 2022 levels

- The increase in total greenhouse gas (GHG) emissions of 1.3 per cent from 2022 levels is above the average rate in the decade preceding the COVID-19 pandemic (2010–2019), when GHG emissions growth averaged 0.8 per cent per year. The rise is in all sources of GHGs, except land use, land-use change and forestry (LULUCF) CO_2, and across all sectors. In 2023 the power sector (i.e. electricity production) continued to be the largest global contributor to emissions at 15.1 $GtCO_2e$, followed by transport (8.4 $GtCO_2e$), agriculture (6.5 $GtCO_2e$) and industry (6.5 $GtCO_2e$) (figure ES.1). Emissions from international aviation, which dropped significantly during the COVID-19 pandemic, showed the highest growth at 19.5 per cent in 2023 from 2022 levels (compared with an average annual growth of 3.1 per cent from 2010 to 2019) clearly indicating a near bounce-back to pre-COVID-19 levels. Other sectors that grew rapidly in 2023 (i.e. at a rate of more than 2.5 per cent) include fugitive emissions from fuel production (oil and gas infrastructure and coal mines), road transportation, and energy-related industry emissions.

Figure ES.1 Total GHG emissions in 2023



2. There are large disparities between the current, per capita and historic emissions of major emitters and world regions

- GHG emissions across the G20 members also increased in 2023 and accounted for 77 per cent of global emissions. If all African Union members are added to the G20 total, more than doubling the number of members from 44 to 99, total emissions increase by just 5 percentage points to 82 per cent. The six largest GHG emitters accounted for 63 per cent of global GHG emissions. By contrast, least developed countries accounted for only 3 per cent (table ES.1).
- Despite significant changes in the past 20 years, large disparities remain between the current average per capita and the historical emissions of major emitters and world regions (table ES.1). For example, average per capita GHG emissions are close to three times higher than the world average of 6.6 tCO_2e in the United States of America and the Russian Federation, while they remain significantly below it in the African Union, India and least developed countries. Consumption-based emissions also remain highly unequal.

Table ES.1 **Total, per capita and historical emissions of selected countries and regions**

	Total GHG emissions in 2023	Change in total GHG emissions, 2022–2023	Per capita GHG emissions in 2023	Historical CO_2 emissions, 1850–2022
	$MtCO_2e$ (% of total)	%	tCO_2e/capita	$GtCO_2$ (% of total)
China	16,000 (30)	+5.2	11	300 (12)
United States of America	5,970 (11)	-1.4	18	527 (20)
India	4,140 (8)	+6.1	2.9	83 (3)
European Union (27 members)	3,230 (6)	-7.5	7.3	301 (12)
Russian Federation	2,660 (5)	+2	19	180 (7)
Brazil	1,300 (2)	+0.1	6.0	119 (5)
African Union (55 members)	3,190 (6)	+0.7	2.2	174 (7)
Least developed countries (45 countries)	1,720 (3)	+1.2	1.5	114 (4)
G20 (excl. African Union)	40,900 (77)	+1.8	8.3	1,990 (77)

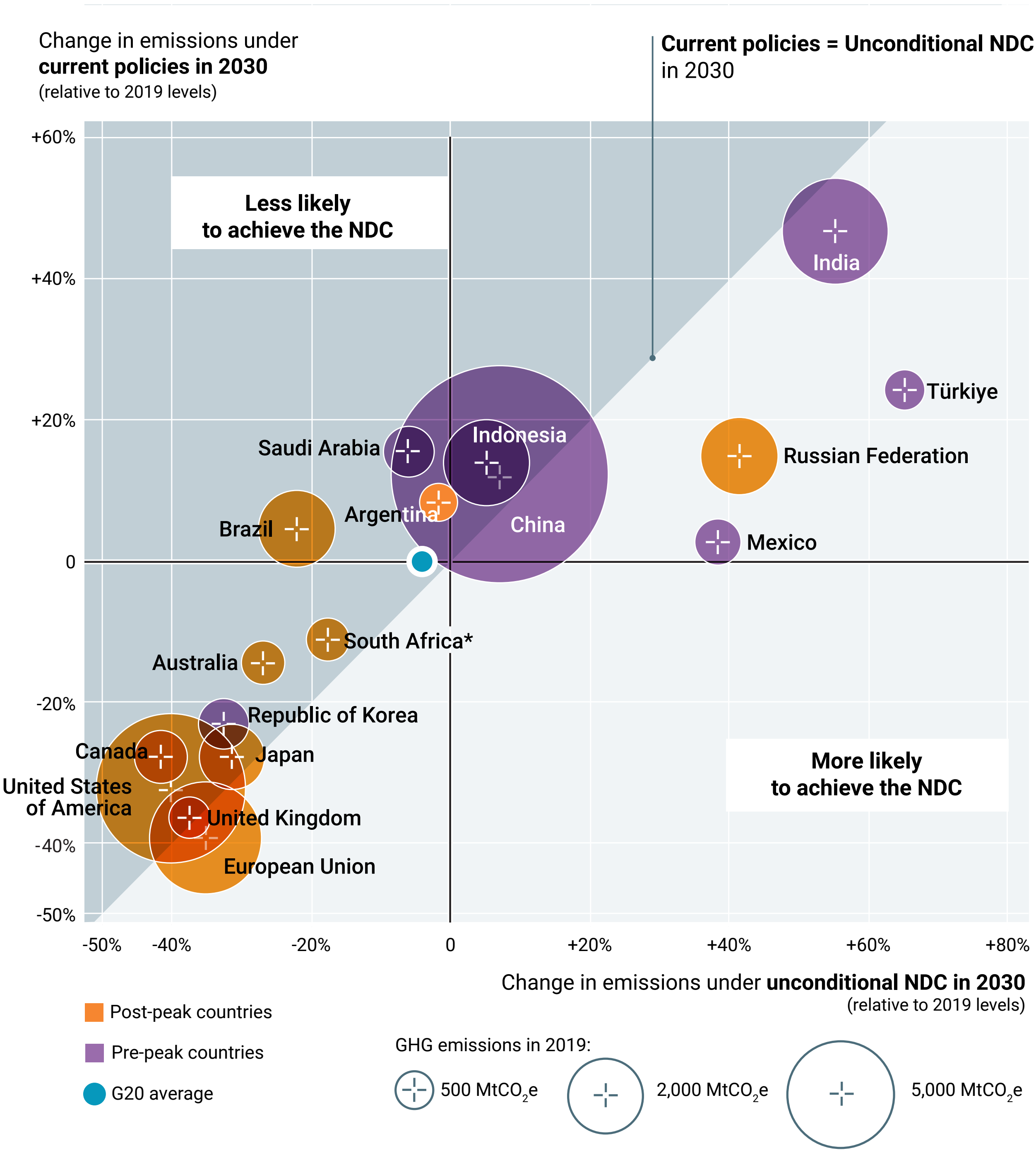
Note: Emissions are calculated on a territorial basis. LULUCF CO_2 emissions are excluded from current and per capita GHG emissions but are included in historical CO_2 emissions based on the bookkeeping approach. Some members of the African Union are also least developed countries.

3. Progress in ambition and action since the initial NDCs plateaued and countries are still off track to deliver on the globally insufficient mitigation pledges for 2030

- Of the parties to the Paris Agreement, 90 per cent have updated or replaced their initial NDC from the time of adoption of the Paris Agreement. However, most of this improvement came in the lead-up to the twenty-sixth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 26) in 2021. Despite requests from the last three COPs to further strengthen 2030 targets, only one country has strengthened its target since COP 28.
- Under current policies, global 2030 emissions are projected to be 57 $GtCO_2e$ (range: 53–59), which is slightly higher than last year's assessment, and around 2 $GtCO_2e$ (range: 0–3 $GtCO_2e$) above the unconditional NDCs and 5 $GtCO_2e$ (range: 2–9 $GtCO_2e$) above the conditional NDCs (table ES.2). This gap in implementation of policies to achieve the NDCs for 2030 is about the same as in last year's assessment.
- Collectively, the G20 members are also still assessed to miss their NDC targets for 2030, with current policy projections exceeding NDC projections by 1 $GtCO_2e$ in 2030. Eleven G20 members are assessed to be off track to achieve their NDC targets with existing policies, and the G20 members projected to meet their NDC target based on current policies currently are those that did not strengthen, or only moderately strengthened, their target levels in their most recent NDCs. Further, collectively the NDC targets of the G20 are far from the average global percentage reductions required to align with 2°C and 1.5°C scenarios (figure ES.2).
- The adoption and implementation of additional and more stringent policies are thus required across countries and sectors to achieve the NDC targets

for 2030. While climate policy has advanced in many countries, there is still a lack of studies that evaluate their effects on GHG emissions in 2030, and it is therefore not possible to assess whether the G20 members' new policies (adopted between June 2023 and June 2024) are likely to significantly affect global emissions in 2030.

Figure ES.2 The landscape of current NDC targets and implementation gaps for the G20 members collectively and individually by 2030, relative to 2019 emissions



Note: * Conditional NDC

4. Implied emissions trajectories of the G20 members towards net zero show reasons for concern

- As at 1 June 2024, 101 parties representing 107 countries and covering approximately 82 per cent of global GHG emissions had adopted net-zero pledges either in law (28 parties), in a policy document such as an NDC or a long-term strategy (56 parties), or in an announcement by a high-level government official (17 parties). All G20 members except Mexico and the African Union (collectively) have set net-zero targets. Overall, however, limited progress has been made since last year's assessment on the key indicators of confidence in net-zero implementation, including legal status, the existence and quality of implementation plans and the alignment of near-term emissions trajectories with net-zero targets.

- Peaking GHG emissions is a prerequisite to achieving net zero. Seven G20 members have not yet peaked emissions, defined as having reached maximum emissions at least five years before the year for which the latest inventory data is available (China, India, Indonesia, Mexico, Saudi Arabia, Republic of Korea, and Türkiye). For these countries, efforts to peak emissions earlier and at a lower level with rapid reductions thereafter will facilitate achievement of their net-zero targets. For most of the ten G20 members where emissions have already peaked (Argentina, Australia, Brazil, Canada, European Union, Japan, Russian Federation, South Africa, United Kingdom of Great Britain and Northern Ireland, United States of America), their rate of decarbonization would need to accelerate – in some cases dramatically – after 2030 to achieve their net-zero goals, unless they accelerate action now and overachieve their 2030 NDC targets. For these countries, accelerating progress in the near term will reduce cumulative emissions while avoiding reliance on unfeasibly rapid decarbonization rates later. The current NDCs and net-zero targets that countries have set themselves suggest a much narrower window of time between peaking and net zero for the countries that have not yet peaked than for those that have.

5. The emissions gap in 2030 and 2035 remains large compared both with pathways limiting warming to 1.5°C and to 2°C

- The emissions gap is defined as the difference between the level of global GHG emissions resulting from full implementation of the most recent NDCs, and levels under least-cost pathways aligned with the Paris Agreement temperature goal.

- The emissions gaps in 2030 and 2035 have remained unchanged since last year's assessment (figure ES.3 and table ES.2), as there have been no submissions of new NDCs with significant implications for global emissions, no updates to the quantifications of their implications, and no updates to the least-cost pathways. To get on track to limiting warming to below 2°C, annual emissions in 2030 need to be 14 $GtCO_2e$ (range: 13–16 $GtCO_2e$, >66 per cent chance) lower than what current unconditional NDCs imply, and 22 $GtCO_2e$ (range: 21–24 $GtCO_2e$, >50 per cent chance) lower for a warming limit of 1.5°C. For 2035, these gaps increase by 4 $GtCO_2e$ for a 2°C warming limit, and 7 $GtCO_2e$ for a 1.5°C limit. If conditional NDCs are also fully implemented, the gaps in 2030 and 2035 for both temperature limits are reduced by around 3 $GtCO_2e$ (figure ES.3).

- The full implementation of unconditional and conditional NDCs reduces expected emissions in 2030 by 4 and 10 per cent, respectively, compared with 2019 levels, whereas a 28 per cent reduction is needed for 2030 emissions to be aligned with 2°C and a 42 per cent reduction for 1.5°C. These estimates are also equivalent to those in last year's assessment. NDCs for 2035 need to reduce global emissions by 37 and 57 per cent below 2019 levels to be compatible with 2°C and 1.5°C, respectively.

- Unless global emissions in 2030 are brought below levels resulting from current policies and from the full implementation of the current NDCs, it will become impossible to get to a pathway that limits global warming to 1.5°C with no or limited overshoot (>50 per cent chance), and strongly increase the challenge of limiting warming to 2°C. Starting from the global emissions implied by the current unconditional NDCs for 2030 would double the required rate of annual emission cuts between 2030 and 2035, relative to immediately enhanced action. Specifically, if action in line with 2°C or 1.5°C pathways were to start in 2024, then global emissions would need to be reduced by an average of 4 and 7.5 per cent every year until 2035, respectively. If enhanced action that goes beyond current unconditional NDCs is delayed until 2030, then the required annual emission reductions rise to an average of 8 per cent and 15 per cent to limit warming to 2°C or 1.5°C, respectively.

Figure ES.3 Global GHG emissions under different scenarios and the emissions gap in 2030 and 2035

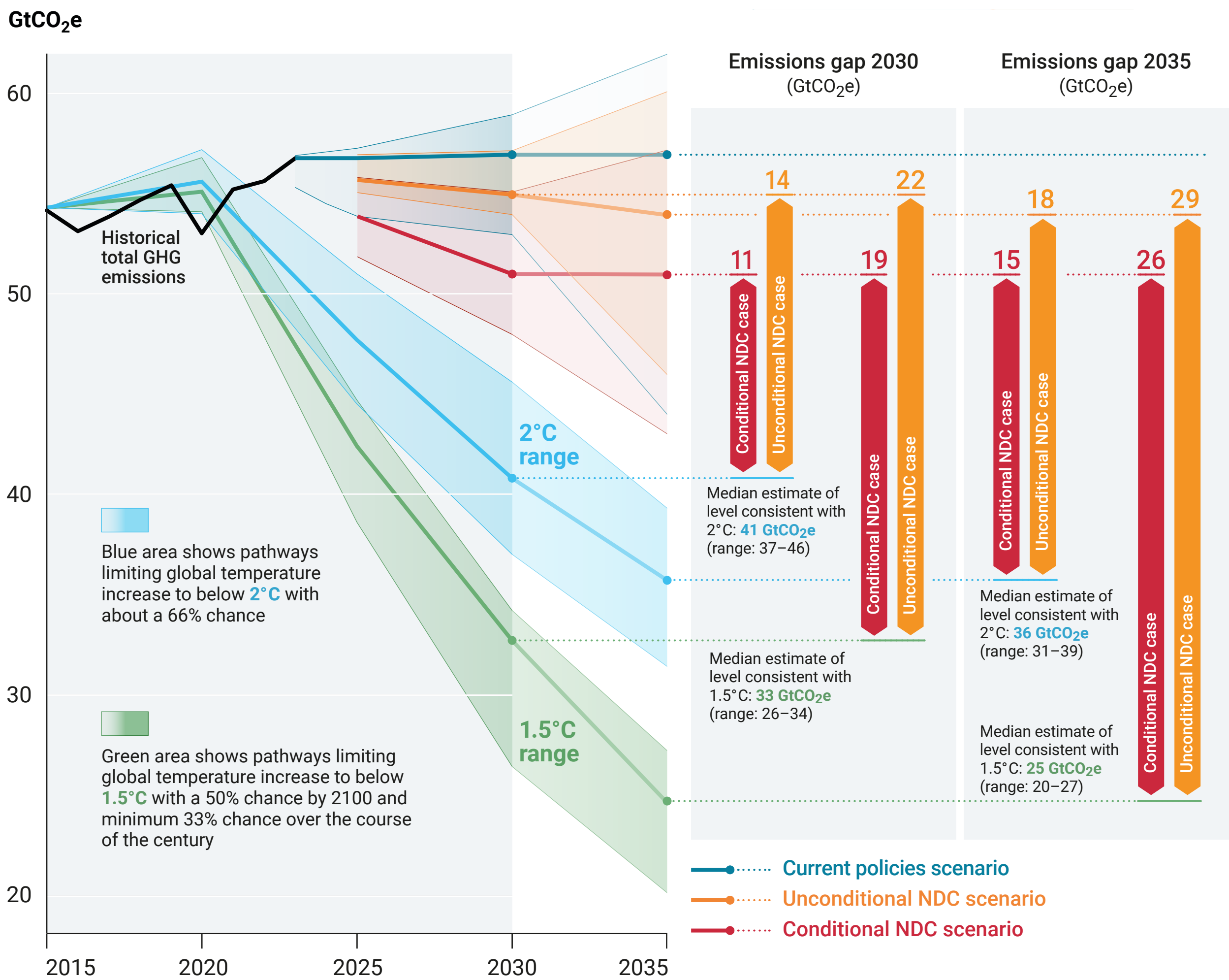


Table ES.2 Global total GHG emissions in 2030, 2035 and 2050, and estimated gaps under different scenarios

Scenario	Projected GHG emissions ($GtCO_2e$)	Estimated emissions gaps ($GtCO_2e$)		
	Median and range	Below 2.0°C	Below 1.8°C	Around 1.5°C
2030				
Current policies	57 (53–59)	16 (12–18)	22 (18–24)	24 (20–26)
Unconditional NDCs	55 (54–57)	14 (13–16)	20 (19–22)	22 (21–24)
Conditional NDCs	51 (48–55)	11 (7–14)	17 (13–20)	19 (15–22)
2035				
Current policies continued	57 (44–62)	21 (9–26)	30 (18–35)	32 (20–37)
Unconditional NDCs continued	54 (46–60)	18 (10–24)	27 (19–33)	29 (21–35)
Conditional NDCs continued	51 (43–57)	15 (8–22)	24 (17–30)	26 (19–33)
Conditional NDCs + all net-zero pledges	43 (38–49)	8 (2–13)	16 (11–22)	19 (13–24)
2050				
Current policies continued	56 (25–68)	36 (4–48)	44 (12–56)	48 (16–60)
Conditional NDCs + all net-zero pledges	19 (6–30)	-1 (-14–10)	7 (-6–18)	11 (-2–22)

6. Time lost since 2020 increases global warming projections and reduces the feasibility of bridging the gap

- The assessment of the emissions gap in 2030 and 2035 is founded on least-cost pathways consistent with limiting warming to 1.5°C, 1.8°C and 2°C. These assume strong mitigation action starting in 2020, resulting in deep GHG reductions this decade. However, following the COVID-19-induced reduction in emissions, global GHG emissions, including methane, have continued to increase.

- The lack of action and time lost has implications. It has reduced the remaining carbon budget, which in 2024 is estimated at 900 $GtCO_2$ for limiting warming to below 2°C (>66 per cent chance) and to 200 $GtCO_2$ to stay below a 1.5°C limit (>50 per cent chance). If the emissions gap is still bridged by 2030, additional cumulative CO_2 emissions in the order of 20–35 Gt will be emitted during 2020–2030 compared with the Paris-aligned pathways. This would result in warming that is about 0.01 to 0.02°C higher than indicated by the original pathways.

- Importantly, inaction reduces the chance of bridging the emissions gap in 2030 because of continued lock-in of carbon-intensive infrastructure and less time available to realize the emission reductions required. It further adds risks of temperature overshoot and compounds increasingly severe climate impacts, some of which are irreversible.

7. Immediate action matters: temperature projections based on the conditional NDC scenario are 0.5°C lower than those based on existing policies

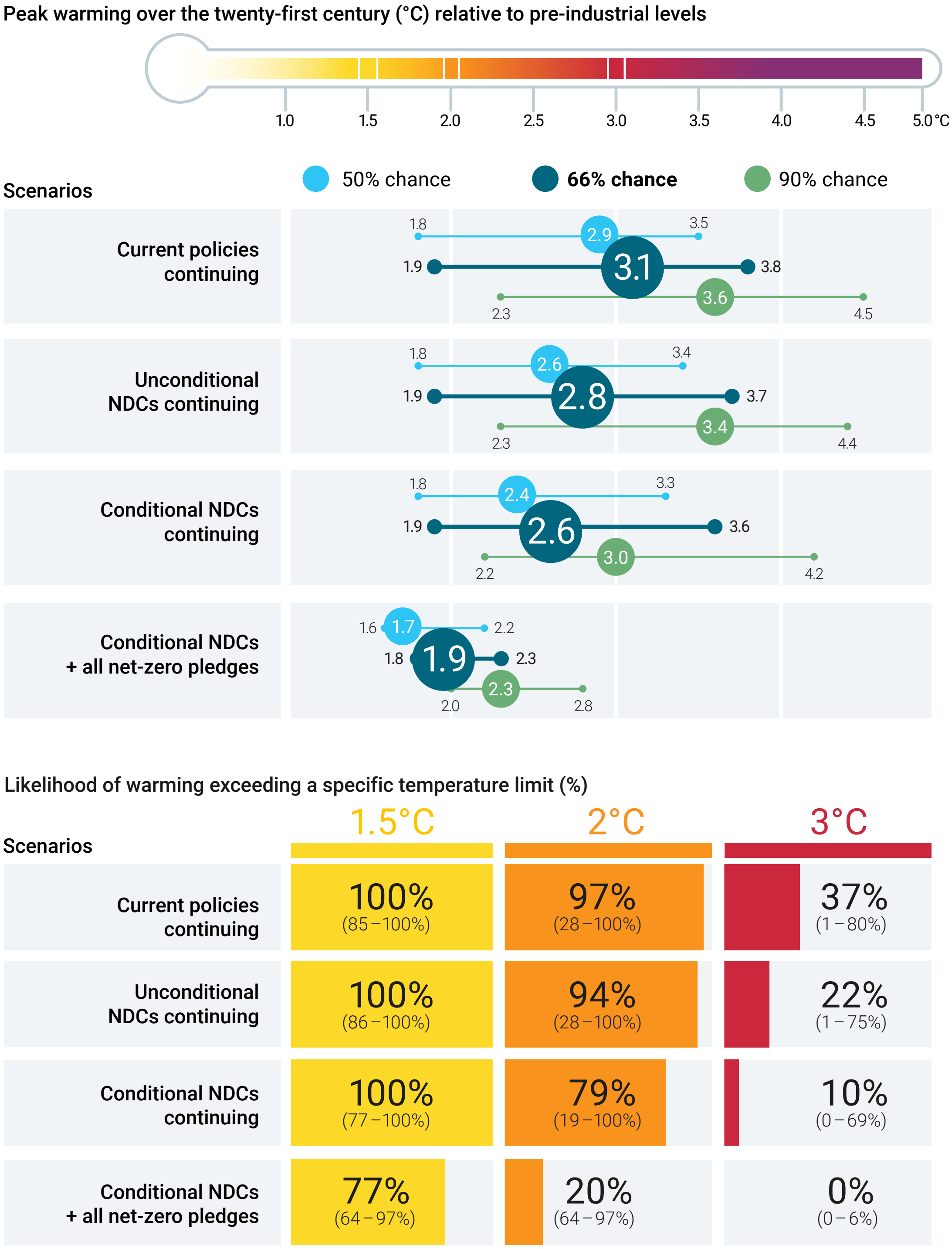
- A continuation of the mitigation effort implied by current policies is estimated to limit global warming to a maximum of 3.1°C (range: 1.9–3.8) over the course of the century. The full implementation and continuation of the level of mitigation effort implied by unconditional or conditional NDC scenarios lower these projections to 2.8°C (range: 1.9–3.7) and 2.6°C (range: 1.9–3.6), respectively. All with at least a 66 per cent chance (figure ES.4).

- Under these three scenarios, central warming projections indicate that the chance of limiting global warming to 1.5°C would be virtually zero (figure ES.4). By mid-century, they imply global warming well above 1.5°C and with up to a 1-in-3 chance that warming already exceeds 2°C by then. As well, warming is expected to increase further after 2100 as CO_2 emissions are not yet projected to reach net-zero levels under these scenarios.

- The only scenario that gets closer to the temperature goal of the Paris Agreement is the most optimistic scenario, which assumes that all the most stringent pledges currently made by countries – in other words the conditional NDCs and all net-zero pledges, including those made as part of long-term low-emissions development strategies – are fully implemented. This scenario is estimated to limit warming over the course of the century to 1.9°C (range: 1.8–2.3, >66 per cent chance). This is also the only pledge-based scenario in which global warming is stabilized over the course of this century.

- These projections highlight the crucial impact of immediate action on likely temperature outcomes, and the need for enhanced support to enable countries achieving the conditional elements of their NDCs. Projections based on the implementation and continuation of the conditional NDC scenario lower peak warming by about 0.5°C compared with those based on current policies. Further, fulfilling near-term conditional NDCs enhances the likelihood of achieving net-zero pledges, which further reduces global warming projections by around 0.5°C. These results emphasize the critical importance of not just achieving but overachieving pledged emission reductions for 2030 in tandem with a quantum leap in ambition in the next NDCs.

Figure ES.4 Projections of global warming under the pledge-based scenarios assessed



8. The G20 has a key responsibility in closing the emissions gap. It is both cost-effective and fair for the G20 to reduce emissions faster than the global average

- The Paris Agreement provides flexibility in translating global goals and milestones into national implementation. Global models can inform our understanding of what is required in terms of national contributions in the next NDCs to get to pathways consistent with the temperature goal of the Paris Agreement. At the same time, national decarbonization scenarios can improve our understanding of feasibility at the individual country level. Both approaches may include considerations of equity and fairness in their development and assessment.

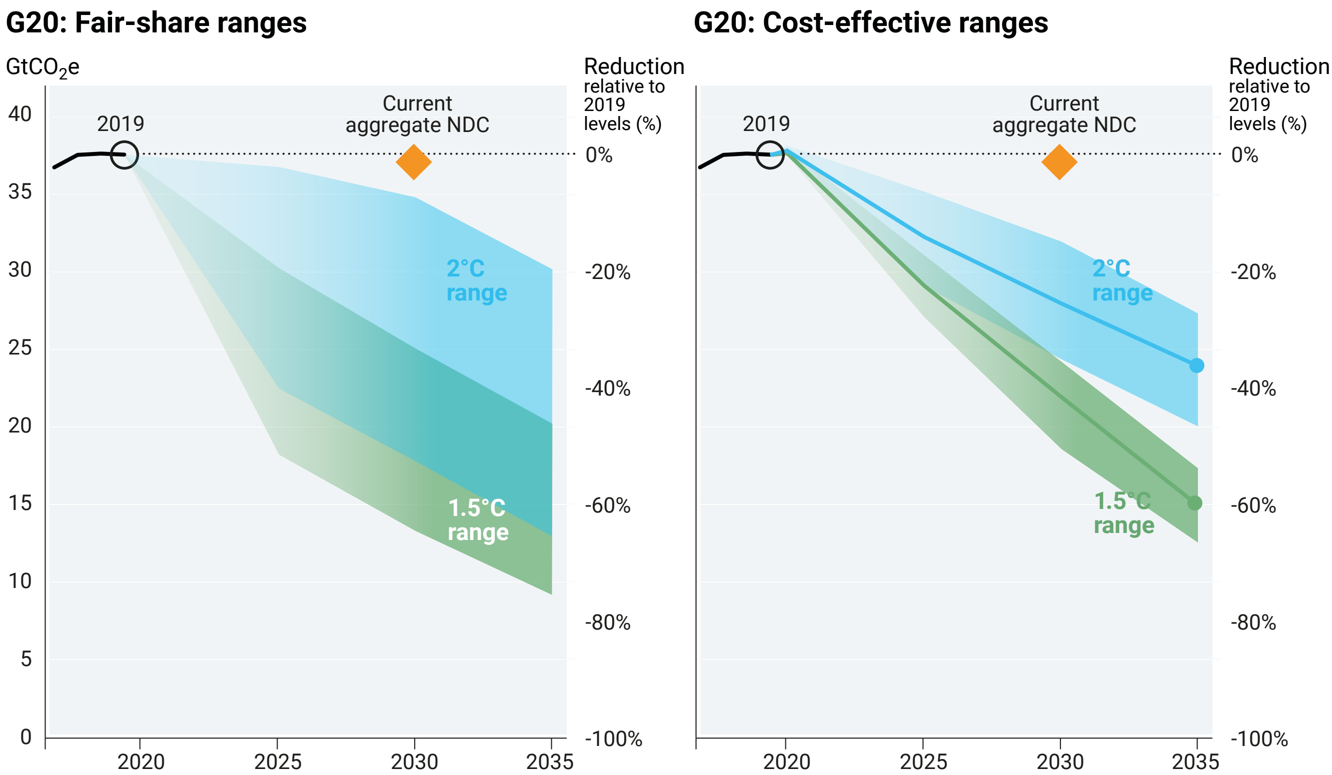
- Illustrative findings show that the G20 members excluding the African Union must go further and faster: current NDC targets for the G20 collectively are neither aligned with cost-effective nor with fair-share pathways consistent with the temperature goal of the Paris Agreement (figure ES.5).

- The G20 is a very heterogeneous group of countries, also based on historical, current and per capita emissions. This means that some G20 members will need to cut their emissions faster than others. In addition, stronger international cooperation and support, including through enhanced climate finance, will be essential for ensuring that the opportunities and efforts of meeting global mitigation and development goals can be realized fairly across G20 members and globally.

- National decarbonization scenarios that achieve national development priorities alongside ambitious mitigation action are emerging for many countries. Several indicate that it is possible – both for G20 members that have peaked emissions and those who are yet to peak – to reduce emissions in 2030 beyond their current NDC targets and to set far higher national ambition for 2035. Such studies can inform interpretations of how countries can reflect the highest possible ambition in their next NDCs, in accordance with article 4 of the Paris Agreement.

- Different approaches can give very different perspectives on what a fair and ambitious NDC would entail. Given these differences, transparency and clarity from individual countries around how their next NDC reflects the highest possible ambition and considers fairness can enable a better-informed evaluation of the next round of NDCs.

Figure ES.5 Illustrative fair-share and cost-effective mitigation ranges consistent with different temperature limits for the G20 collectively, excluding the African Union and excluding LULUCF



9. Emission reduction potentials for 2030 and 2035 are substantial, but time is short and realizing the potentials requires overcoming persisting challenges and massively boosting policies, support and finance

- Progress towards detailed sectoral benchmarks identified in the literature to be consistent with 1.5°C pathways falls woefully short of the systems transformation required. The next round of NDCs presents an opportunity for countries to incorporate ambitious sectoral targets and plans – and there are abundant opportunities to do so.

- An updated assessment of sectoral GHG emission reduction potentials shows that the techno-economic mitigation potential at costs below US$200/t$CO_2$e is sufficient to bridge the emissions gap identified for 2030 and 2035. The potential is assessed at 31 GtCO_2e/year in 2030 (range: 25–35) and 41 GtCO_2e/year in 2035 (range: 36-46) (figure ES.6).

- Remarkably, increased deployment of just two proven and cost-competitive options – solar photovoltaic and wind energy – makes up 27 per cent of the total emission reduction potential in 2030 and 38 per cent in 2035. In forestry, reduced deforestation, increased reforestation and improved forest management present readily available low-cost options with large emission reduction potentials of about 19 and 20 per cent of the total potential in 2030 and 2035, respectively. Other important and readily available mitigation options include demand-side measures, efficiency measures, and electrification and fuel switching in the buildings, transport and industry sectors.

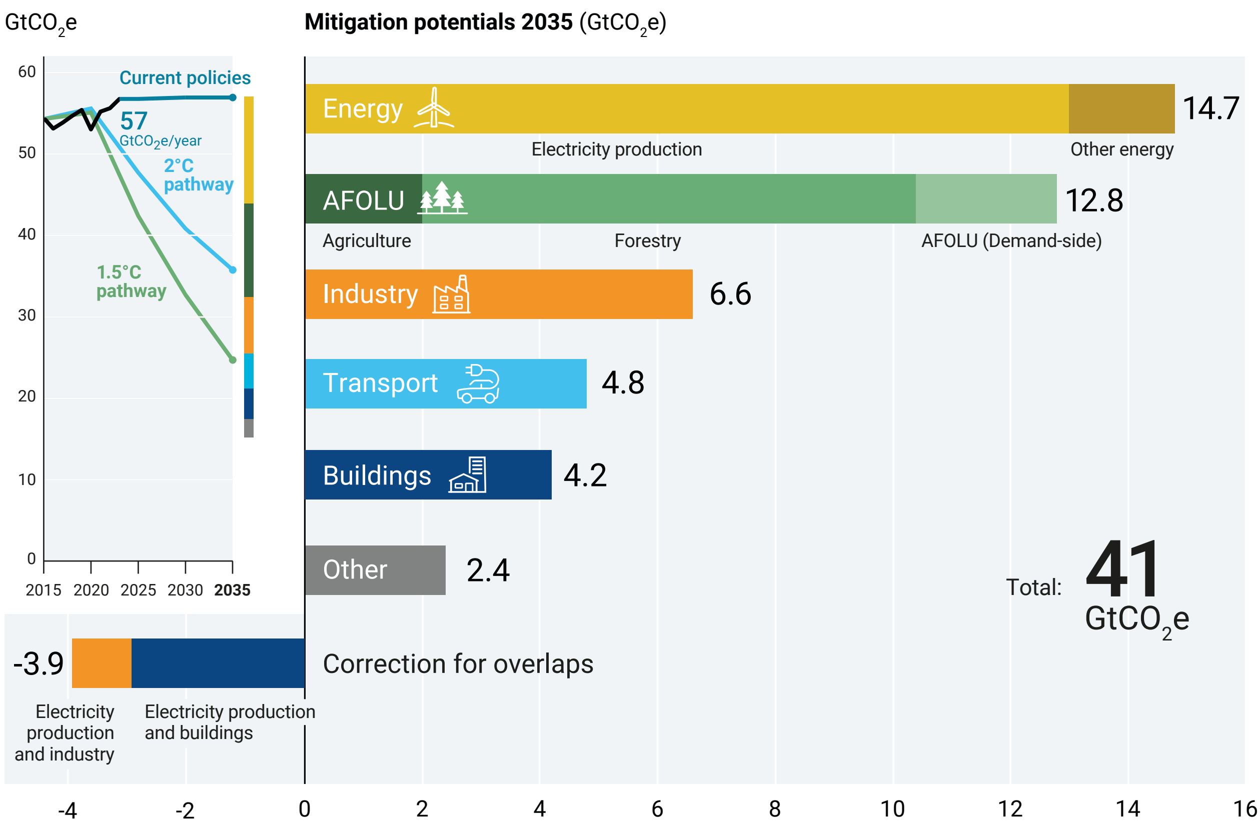
- Realizing these mitigation potentials, even partially, requires rapid and unprecedented policy action globally, employing a whole-of-government approach that emphasizes sustainable and climate-resilient development, effectively addresses barriers and catalyses public and private sector action.

- Mitigation measures that are designed and deployed in response to the needs of multiple stakeholders and that maximize socioeconomic and environmental co-benefits and reduce trade-offs have a much greater chance of being successful and scaled up.

- Realizing the mitigation potentials will also require a substantial increase in investment. Overall, alignment with 1.5°C scenarios is assessed to require at least a sixfold increase in mitigation investment — accompanied by a shift in investment patterns, focusing on mitigation activities and directing international funding towards emerging market and developing economies outside of China. These regions face pressing development needs, yet investment growth has stagnated since the 2008 global financial crisis.

- Only a small share of these investments would be incremental, as considerable investments would be needed each year to meet the growing demand for energy and other development needs, especially in emerging market and developing economies. The estimated global incremental investment for a net-zero transition is US$0.9 trillion to US$2.1 trillion per year between 2021 and 2050, which is substantial but manageable in the broader context of the close-to-US$110 trillion global economy and financial markets.

Figure ES.6 **Overview of annual mitigation potentials by 2035 by sector up to US$200/t$CO_2$e**

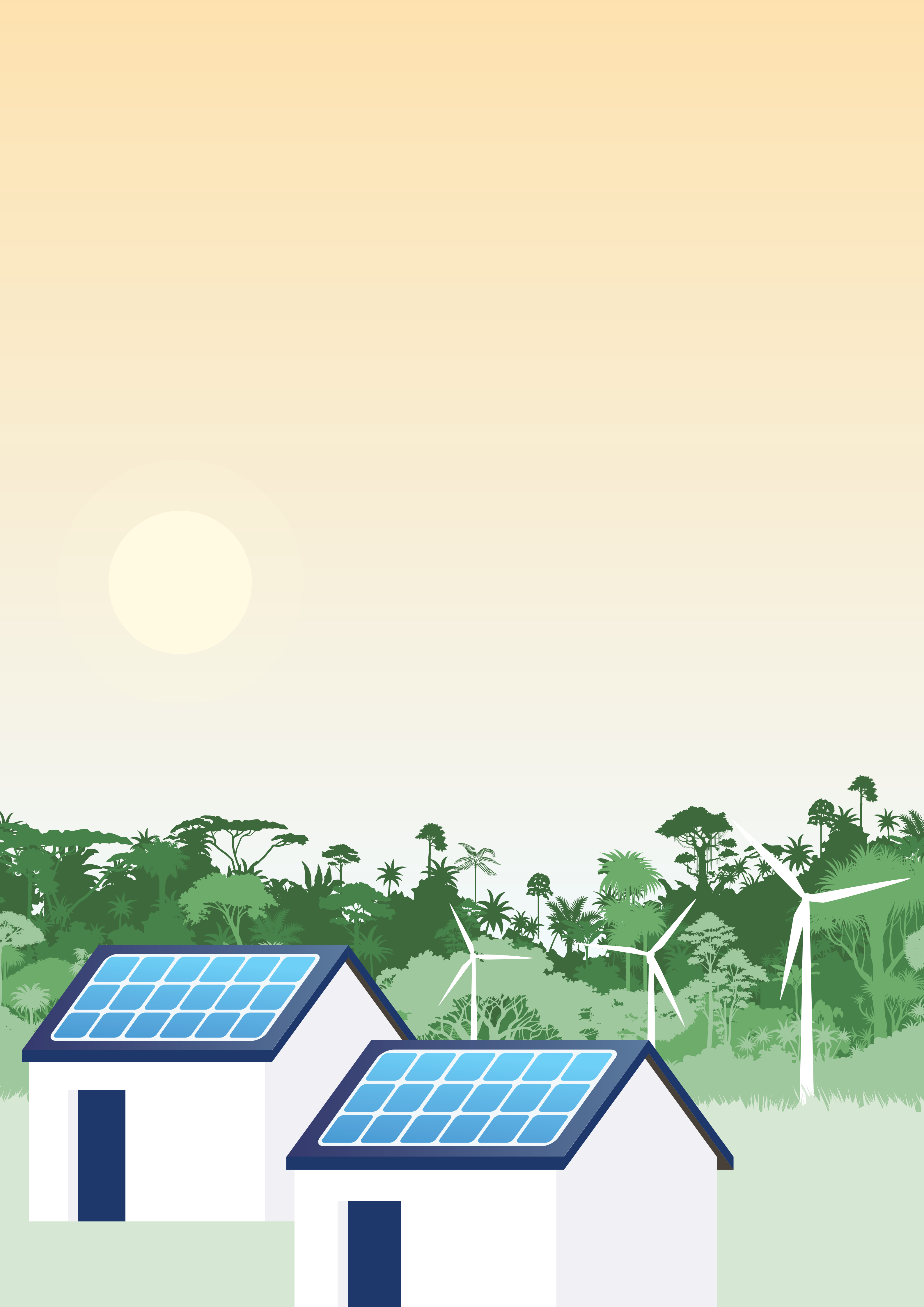


What are the implications for the next NDCs?

The Paris Agreement, along with subsequent COP decisions, sets the framework, requirements and expectations for the next NDCs, which are to contain targets and measures for 2035 and to be communicated by February 2025. These should reflect the latest science, demonstrate progress from previous NDCs and explain how they reflect the highest possible ambition and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. The outcome of the first global stocktake at COP 28 urges countries to align their NDCs with limiting global warming to 1.5°C and long-term low-emissions development pathways towards just transitions to net zero. It calls for countries to set sector-specific global mitigation efforts, including the tripling of renewable energy capacity by 2030, doubling of the global average annual rate of energy efficiency improvements by 2030, transitioning away from fossil fuels in energy systems, and conserving, protecting and restoring nature and ecosystems – encouraging parties to contribute to these in a nationally determined manner.

In accordance with other recently developed guidelines for the next round of NDCs, this year's assessment suggests that countries should consider the following suggestions as they prepare their next NDCs:

- Meet the highest standards: including all gases listed in the Kyoto Protocol, covering all sectors, setting specific, quantitative targets in relation to a base year and being explicit about conditional and unconditional elements.
- Detail how national plans that prioritize national development and progress towards the Sustainable Development Goals, including resilience, adaptation and just transition, are consistent with ambitious efforts to reduce emissions.
- Be transparent and clear about how the NDC submission reflects both a fair share and the highest possible ambition, given the requirement for all countries to make pledges that reflect their level of development, their historical emissions and their current contribution to global warming via both territorial and consumption emissions.
- Include detailed implementation plans that pursue options for accelerating mitigation action now and significantly more ambitious mitigation targets for 2035. These should consider sectoral benchmarks and all mitigation options and potentials relevant in national contexts. They should also explain how the plans contribute to tripling renewable capacity deployment and doubling annual energy efficiency rates by 2030 and to transitioning away from fossil fuels. And they should describe mechanisms for review and accountability.
- Use the NDCs to be explicit about conditional and unconditional elements, with emerging market and developing economies providing details on the means of implementation they need, including institutional and policy change, as well as international support and finance required to achieve ambitious NDC targets for 2035.



1 Introduction

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1.1 All eyes on the next nationally determined contributions

Over the coming months, countries have the opportunity – and obligation – to prepare and submit new nationally determined contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC), as specified in the Paris Agreement and as part of its five-year ambition-raising cycle. If sufficient, the collective ambition of these NDCs could bridge the emissions gap in 2035 between emissions under the full implementation of countries' mitigation pledges and levels consistent with pathways that limit global warming to well below 2°C, while pursuing efforts to limit the increase to 1.5°C above pre-industrial levels.

This fifteenth Emissions Gap Report has a special focus on what is required from the next NDCs to maintain the possibility of achieving this long-term temperature goal of the Paris Agreement. It underscores that ambition means nothing without action: unless global emissions in 2030 are brought below levels implied by existing policies and current NDCs, it will become impossible to get on a pathway that limits global warming to 1.5°C with no or limited overshoot (>50 per cent chance), and it will strongly increase the challenge of limiting warming to 2°C (>66 per cent chance). The next NDCs must deliver a quantum leap in ambition, in tandem with accelerated mitigation action in this decade.

The Paris Agreement, along with decisions adopted at subsequent UNFCCC Conferences of the Parties (COPs), sets the framework, requirements and expectations for the next NDCs, which are to contain targets and measures for 2035 and are to be communicated by February 2025 (UNFCCC 2024, paragraph 166). These should reflect the latest science, show progress from the previous ones, and explain how they reflect the highest possible ambition as well as the principle of common but differentiated responsibilities and respective capabilities in light of different national circumstances (Paris Agreement 2015).

The outcome of the first global stocktake adopted at COP 28[1] specifically encourages countries to come forward with ambitious and economy-wide emission reduction targets covering all greenhouse gases (GHGs), sectors and categories, and to align their NDCs with limiting global warming to 1.5°C and with long-term low-emission development pathways towards just transitions to net zero (UNFCCC 2024). The global stocktake outcome also calls for countries to contribute in a nationally determined manner to sector-specific global mitigation efforts, including: the tripling of renewable energy capacity by 2030; the doubling of the global average annual rate of energy efficiency improvements by 2030, transitioning away from fossil fuels in energy systems; and conserving, protecting and restoring nature and ecosystems (UNFCCC 2024, paragraph 28). Importantly, the Katowice Rulebook on the implementation of the Paris Agreement requires Parties to explain how the preparation of their NDCs was informed by the outcomes of the global stocktake, in accordance with article 4, paragraph 9 of the Paris Agreement.

In addition to the preparation of their next NDCs, countries are encouraged to submit new or revised long-term low-emission development strategies by November 2024, and to submit their first biennial transparency reports, which will provide information about their progress towards achieving the NDCs by the end of 2024.

While the challenge of bridging the emissions gap in 2030 and the potential gap in 2035 is indisputable, there are abundant opportunities for immediately accelerating mitigation action alongside achieving pressing development needs and fulfilling the Sustainable Development Goals. Technology

1 As part of the Paris Agreement, global stocktakes are held every five years to assess the global response to the climate crisis and chart a better way forward. Parties agreed to undertake the first global stocktake in 2023, which concluded at COP 28 in Dubai, and every five years thereafter.

developments, particularly in wind and solar energy, continue to exceed expectations, lowering deployment costs and driving their market expansion. This report finds that the G20 has a key responsibility in closing the emissions gap, and that it is both cost-effective and fair for the G20 to reduce emissions faster than the global average (chapter 5). The updated assessment of sectoral emission reduction potentials included in this year's report (chapter 6) shows that the emission reduction potentials based on existing technologies and at costs below US$200/ton of carbon dioxide equivalent is sufficient to bridge the emissions gap in 2030 and 2035. This will, however, require overcoming formidable policy, governance, institutional and technical barriers, and it will require an unprecedented increase in the support provided to developing countries along with a redesigning of the international financial architecture.

1.2 Approach and structure of this report

Every year since 2010, the United Nations Environment Programme (UNEP) has published the Emissions Gap Report as an independent science-based assessment to inform international negotiations under the UNFCCC about the gap between pledged GHG emission reductions and the reductions needed to align with the long-term temperature goal of the Paris Agreement, the implications of this gap and opportunities to bridge it. It is an assessment report, based on a synthesis of the latest scientific literature, models, and data analysis and interpretation, including those published by the Intergovernmental Panel on Climate Change.

This report is organized into six chapters including this introduction. Chapter 2 assesses the trends in global GHG emissions. Chapter 3 provides a global update of NDCs and long-term net-zero-emissions pledges, reflecting on the implications for the next NDCs, and it assesses the progress of G20 members towards achieving their current NDC targets and their and net-zero-emissions pledges. Chapter 4 updates the assessment of the emissions gap by 2030 and 2035 based on the latest NDCs, and it includes an assessment of the implications of time lost due to insufficient mitigation action. It also considers the implications of the emissions gap on the feasibility of achieving the long-term temperature goal of the Paris Agreement. Chapter 5 provides illustrative examples of how the global goals and milestones of the Paris Agreement could be translated into national implementation. It shows how global models can inform our understanding of what is required in terms of national contributions in the next NDCs to get to pathways consistent with the temperature goal of the Paris Agreement, whereas national decarbonization scenarios can improve our understanding of feasibility at the individual country level. Finally, chapter 6 provides an overview of sectoral benchmarks as well as emission reduction potentials and opportunities that can inform the preparation of the next NDCs, while stressing the investment needs and the needs for substantial increases in support, including finance to emerging market and developing economies to realize the required emission reductions.

As in previous years, this Emissions Gap Report has been prepared by an international team of leading experts. This year, 58 leading scientists from 40 expert institutions across 18 countries have been engaged in producing the report. The assessment process has been overseen by an international steering committee, and it has been transparent and participatory. Geographical diversity and gender balance has been considered to the extent possible. All chapters have undergone external review, and the assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report, to provide them with the opportunity to comment on the findings.

It is the hope of UNEP that the information contained in this report will be useful for international climate change discussions and for countries, especially as they prepare their next NDCs.

2 Global emissions trends

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2.1 Introduction

This chapter assesses greenhouse gas (GHG) emissions trends up to and including 2023. It starts with global trends by GHGs (section 2.2) before describing trends by sector (section 2.3) and the emissions of major emitters (section 2.4). In doing so, it sets the stage for subsequent chapters that assess climate policy progress of G20 members and the emissions gap.

This chapter provides multiple perspectives on national emissions (including total, per capita and historic emissions) as well as recent trends. Each of these perspectives offer insight into inequalities in contributions to climate change. They also highlight that reversing global emissions growth now requires urgent efforts to substantially reduce fossil fuel use and deforestation, make ambitious efforts to reduce non-carbon dioxide (non-CO_2) GHG emissions and to reduce end-use demand where possible.

As in previous years, the Emissions Gap Report focuses on total net GHG emissions across all major groups of anthropogenic sources and sinks reported under the United Nations Framework Convention on Climate Change (UNFCCC). This includes carbon dioxide (CO_2) emissions from fossil fuels and industry (fossil CO_2), CO_2 emissions and removals from land use, land-use change and forestry (LULUCF CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions. It includes fluorinated gas (F-gas) emissions reported under the UNFCCC, but excludes F-gas emissions regulated under the Montreal Protocol on ozone-depleting substances, which accounted for approximately 1.5 gigatons of CO_2 equivalent ($GtCO_2e$) in 2022 (Forster *et al.* 2024). It also excludes the global cement carbonation sink, which accounted for approximately -0.8 $GtCO_2e$ in 2022 (Friedlingstein *et al.* 2023). Where estimates are reported at a national level, these are based on territorial accounting.

Following the change in methodology outlined in the Emissions Gap Report 2022 (United Nations Environment Programme [UNEP] 2022), the global bookkeeping approach is used to report global estimates of net LULUCF CO_2 emissions and the national inventory approach is used to report national estimates of net LULUCF CO_2 emissions. This ensures that global estimates are consistent with those of chapter 4 as well as the carbon cycle and climate science literature, while national estimates are consistent with those reported by countries to the UNFCCC. As this chapter reports, total net LULUCF CO_2 emissions differ substantially between these two approaches, due to known differences in system boundaries and other assumptions (Grassi *et al.* 2018). A translation between global emissions based on bookkeeping models and the national GHG inventories reported by countries is available and updated annually (Friedlingstein *et al.* 2023; Grassi *et al.* 2023).

The principal sources in this chapter include: the Emissions Database for Global Atmospheric Research (EDGAR) data set for fossil CO_2, CH_4, N_2O and F-gas emissions (Crippa *et al.* 2024); the Global Carbon Budget for cement carbonation CO_2 and global LULUCF CO_2 estimates, taking the average of three bookkeeping models (Friedlingstein *et al.* 2023); and Grassi *et al.* (2022) for national inventory-based LULUCF CO_2 (with updates to the latest inventories for the major emitters). Throughout this report, 100-year global warming potentials from the latest Intergovernmental Panel on Climate Change Working Group I *Sixth Assessment Report* (IPCC WGI AR6) (Forster *et al.* 2021) are used where GHG emissions are aggregated to CO_2 equivalents. Alternative metrics can be used to highlight the differing impacts of short-lived gases, but are not explored here. Further methodological and data choices are detailed in appendix A of this chapter, which is available online.

2.2 Global emissions increased in 2023

Global GHG emissions reached a record high of 57.1 $GtCO_2e$ in 2023, growing by 1.3 per cent (0.7 $GtCO_2e$) from the previous year (figure 2.1; table 2.1) (Crippa *et al.* 2024).[1] This rate is above the average rate in the decade preceding the COVID-19 pandemic (2010–2019), when GHG emissions growth averaged 0.8 per cent per year. At the same time, atmospheric CO_2 concentrations continued to rise and will continue to do so until annual CO_2 emissions are reduced sufficiently to be balanced by removals (net zero).

Box 2.1 The impacts of climate-related events on GHG emissions

Climate change can itself drive changes in anthropogenic emissions as well as natural emissions and uptakes. Examples include the effect of warming on increases in wildfire events, the amount of carbon intake by vegetation, or on energy supply and demand patterns. Increased emissions from these sources could in turn further exacerbate climate change.

Wildfires, unprecedented in instrumental records, were witnessed in many regions in recent years, with significant emissions impacts (Clarke *et al.* 2022; Jones *et al.* 2024). An estimated 8.8 $GtCO_2$ emissions were released in the March 2023–February 2024 fire season (Jones *et al.* 2024). However, it is difficult to assess whether these are 'natural' wildfires or if they can be classed as 'anthropogenic' due to the impact of climate change. Further, burnt areas generally recover from fires and draw down the CO_2 emitted during the fire, albeit over a period of decades. For these reasons, global assessments of anthropogenic emissions in IPCC reports and the Global Carbon Budget have only included the CO_2 emissions from wildfires that are associated with permanent land-use change, as in the case of tropical deforestation fires (Friedlingstein *et al.* 2023). Other wildfire emissions and their subsequent removals are classified as natural or not directly anthropogenic, and are counted towards natural terrestrial sinks and sources in these assessments. A similar approach is adopted here and only the CO_2 fire emissions associated with land-use change are included. It excludes, for example, the major boreal forest fires that occurred in Canada last year.

Although they are excluded from this assessment, non-anthropogenic emissions and sinks are critical to future climate forcing. Attribution studies indicate that climate change is resulting in an increased risk of fires, raising concerns about the fragility and permanence of forest ecosystems and their carbon stocks (Carnicer *et al.* 2022; Clarke *et al.* 2022). CH_4 emissions from wetlands and permafrost biomes are also known to increase in response to warmer conditions (Peng *et al.* 2022; Saunois *et al.* 2024). Such climate feedbacks will compromise our ability to meet global temperate objectives, even if countries achieve ambitious reductions.

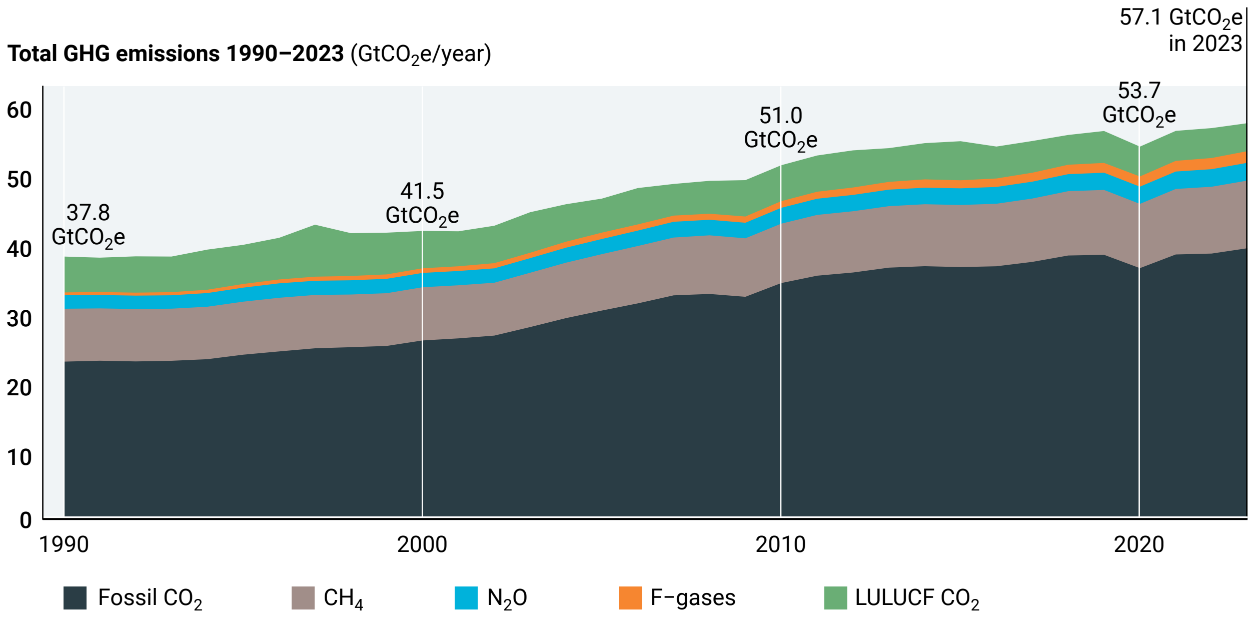
A changing climate can also influence short-term shifts in energy supply and demand. However, the magnitude of change depends on several factors (van Ruijven, De Cian and Wing 2019). Recent evidence shows that several regions have experienced annual rises in climate-induced cooling demand and cooling degree days, particularly in Asia, Africa and the Arabian Peninsula (Scoccimarro *et al.* 2023; Staffell, Pfenninger and Johnson 2023). Weather patterns can drive large fluctuations in energy demand for heating and cooling, with subsequent emissions impacts (International Energy Agency [IEA] 2024a). Extreme and prolonged drought also resulted in a significant global decline in hydropower generation in 2023, led by China, the United States of America, India and other parts of Asia, despite an increase in capacity additions of 20 gigawatts (IEA 2024b). Overall, a changing climate adds more variability to levels of energy demand and available supply options (Liu *et al.* 2023), while extreme weather can disrupt energy supply and transmission, all of which can alter short-term emission trends. In the agriculture sector, warming can also directly increase emissions from soils, rice cultivation and land clearing, and indirectly by driving up intensive irrigation and agrochemical needs (Yang *et al.* 2024).

There remains considerable uncertainty in terms of how climate change affects emissions. Climate resilience measures will be crucial to avoiding impacts, especially on vulnerable populations (i.e. due to low income, age, gender, ethnicity or combinations thereof).

1 Global GHG emissions in 2023 were 56.8 $GtCO_2e$ when assessed with global warming potentials with a 100-year time horizon from the Intergovernmental Panel on Climate Change *Fifth Assessment Report*. The time series data sets used for the Emissions Gap Report are updated on an annual basis to provide the most up-to-date global emissions estimates. This implies changes. The latest estimates were revised to include more detailed information on methane emissions, lowering global annual estimates by ~1$GtCO_2e$ over the past decade (see appendix A).

Fossil CO_2 emissions account for approximately 68 per cent of current GHG emissions. These emissions are driven by the combustion of coal, oil and gas in the energy sector, as well as industrial processes associated with the manufacture of metals, cement and other materials. Multiple data sets agree that fossil CO_2 emissions grew in 2023: EDGAR (used here) estimates an increase of 2 per cent (Crippa *et al.* 2024), compared with +1.6 per cent reported by the Energy Institute (2024) (energy sector only) and +1.1 per cent forecast by the Global Carbon Budget (Friedlingstein *et al.* 2023). According to EDGAR, fossil CO_2 was the main contributor to the overall increase in GHG emissions and grew significantly faster compared with 2021–2022 (0.3 per cent).

Figure 2.1 Total net anthropogenic GHG emissions, 1990–2023



Note: Non-CO_2 GHGs are converted to CO_2e using global warming potentials with a 100-year time horizon from the IPCC WGI AR6 (Forster *et al.* 2021).

Sources: Crippa *et al.* (2024); Friedlingstein *et al.* (2023).

Together, CH_4, N_2O and F-gas emissions account for about 25 per cent of total GHG emissions. Emissions of all these gases continued to grow in 2023, with F-gas at the fastest rate at 4.2 per cent, followed by CH_4 at 1.3 per cent and N_2O at 1.1 per cent. Anthropogenic CH_4 emissions are currently the second largest source of GHG emissions, and are mainly attributable to ruminant livestock and manure management, rice cultivation, venting from oil and gas operations, coal mines and waste management – all of which increased in 2023 (figure 2.2, section 2.3).

Global net LULUCF CO_2 emissions – using the global bookkeeping approach – declined by 6.5 per cent in 2023, but are based on an early projection of land-use activity with relatively high uncertainties (Friedlingstein *et al.* 2023). Net LULUCF CO_2 emissions have slowly declined in the past two decades from a peak in the mid-1990s and currently account for about 7 per cent of global GHG emissions. LULUCF CO_2 emissions and removals continue to have the largest uncertainties of all gases considered here, both in terms of their absolute amounts and trends.

Global bookkeeping and national inventory-based accounts of LULUCF CO_2 emissions diverged by approximately 7 $GtCO_2$ in 2021 (table 2.1). This is due to known differences in system boundaries between each approach, in particular the fact that bookkeeping models consider only 'direct' human-induced fluxes as anthropogenic (e.g. deforestation, afforestation and other land use-related vegetation changes), whereas national inventories typically also include most of the 'indirect' human-induced fluxes (e.g. enhanced vegetation growth due to increased atmospheric CO_2) that occur on managed land (Grassi *et al.* 2021; see box 2.1 in the Emissions Gap Report 2022). As a result, national inventories globally sum up to a small net LULUCF CO_2 removal, but include a large portion of removals that are not the result of management action and will not be sustained once atmospheric CO_2 levels stabilize and decline (Gidden *et al.* 2023).

Table 2.1 **Total global emissions by source**

$GtCO_2e$	2023	2022	2021	2010–2019 (average)
GHG	57.1±5.4	56.3±5.4	55.9±5.4	53.8±5.5
Fossil CO_2	39±3.1	38.2±3.1	38.1±3	36.3±2.9
LULUCF CO_2 (global bookkeeping)	4±2.8	4.3±3	4.3±3	5±3.5
LULUCF CO_2 (national inventory*)	-	-	-2.8±-2	-2.9±-2
CH_4	9.8±2.9	9.6±2.9	9.4±2.8	9±2.7
N_2O	2.6±1.5	2.5±1.5	2.5±1.5	2.4±1.4
F-gases	1.7±0.5	1.6±0.48	1.5±0.46	1.2±0.35

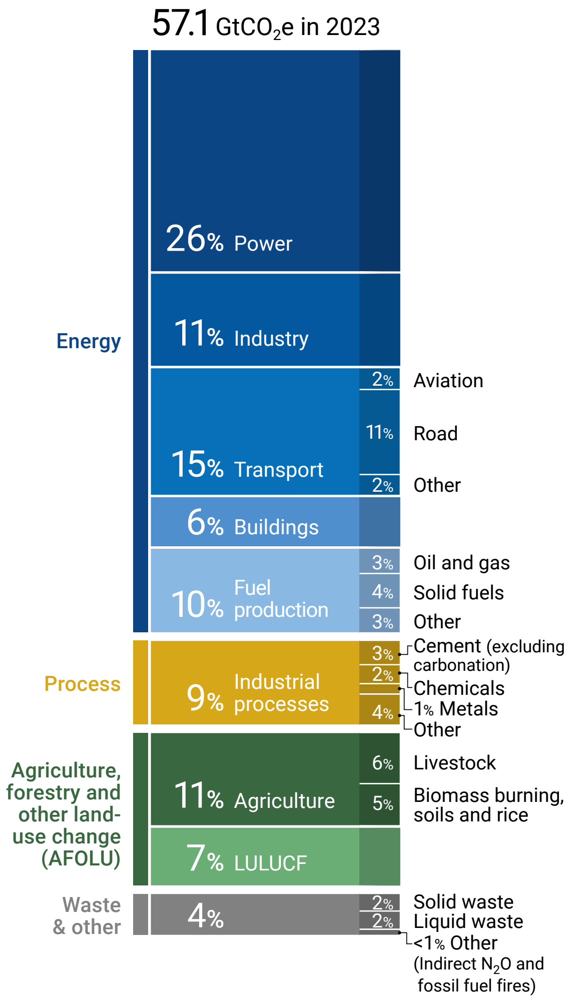
Note: Non-CO_2 GHGs are converted to CO_2e using global warming potentials with a 100-year time horizon from the IPCC WGI AR6 (Forster *et al.* 2021). Fossil CO_2 excludes the cement carbonation sink, which accounted for -0.8 $GtCO_2$ in 2022. *Inventory-based LULUCF CO_2 is excluded from total GHG emissions, but all other sources are included.

Source: Crippa *et al.* 2024; Friedlingstein *et al.* (2023); Grassi *et al.* (2022).

2.3 Sectors are shifting towards renewable sources and electrification, but not yet fast enough to significantly displace fossil fuels

GHG emissions occur in different economic sectors, and are driven by varying activities and socioeconomic processes. Figure 2.2 depicts global emissions by sector, allocating emissions on a production basis (i.e. the sectors in which emissions occur). By this classification, in 2023, the power sector (i.e. electricity production) was the largest global contributor to emissions at 15.1 $GtCO_2e$, followed by transport (8.4 $GtCO_2e$), agriculture (6.5 $GtCO_2e$) and industry (6.5 $GtCO_2e$).

Figure 2.2 Total GHG emissions by sector



Note: Table A.4 in appendix A describes the sectors introduced here and their main sources of emissions.

Source: Crippa *et al.* (2024); Friedlingstein *et al.* (2023).

Different allocations of emissions are possible and can highlight other perspectives on sectoral contributions to climate change. For instance, power sector emissions can be reallocated to the end-use sectors where electricity and heat is consumed (Lamb *et al.* 2021). This brings more focus on industry and buildings, and highlights the importance of a demand perspective for climate policy and action (Creutzig *et al.* 2022). Other approaches can highlight the relevance of consumption and international trade (Peters *et al.* 2011), the food system (Cerutti *et al.* 2023; Li *et al.* 2023), cities (Crippa *et al.* 2021) or fossil fuel producers (Carbon Majors 2024).

In terms of recent growth, emissions from international aviation, which dropped significantly during the COVID-19 pandemic, showed the highest change at 19.5 per cent in 2023 from 2022 levels (compared with an average annual growth of 3.1 per cent from 2010–2019), clearly indicating a near bounce back to pre-COVID levels. Other sectors that grew rapidly in 2023 (i.e. at a rate of more than 2.5 per cent) included fuel production (oil and gas, solid fuels), road transportation and energy-related industry emissions (figure 2.2). Collectively these trends need to be reversed for global peaking to occur.

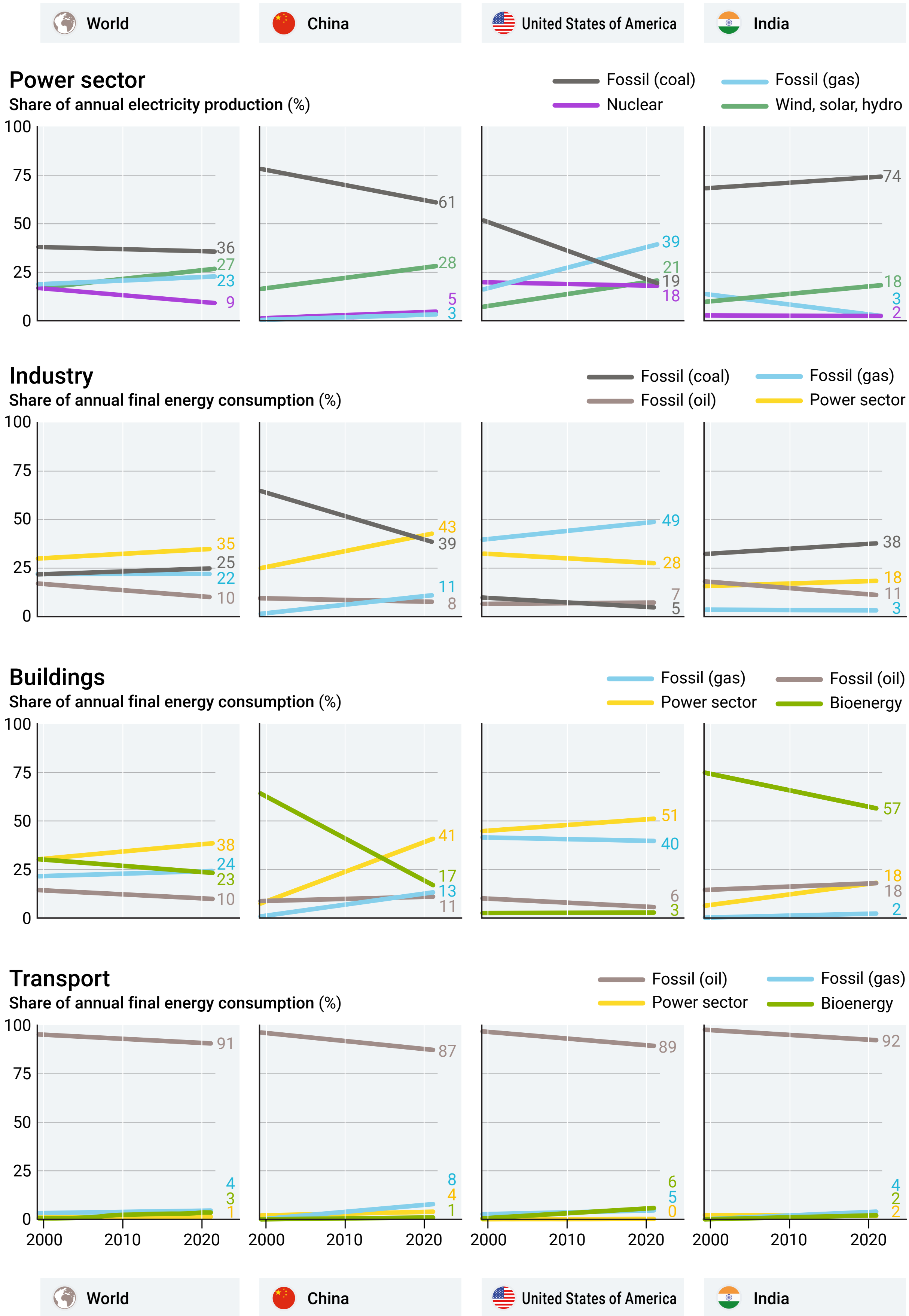
A key driver of GHG emissions in different sectors is activity levels, which have generally grown at a global level and across all major sectors – apart from transport during and after the COVID-19 pandemic (see table A.5 in appendix A). Energy consumption trends vary by country, and are generally increasing in China and India, stable in the United States of America and decreasing across all sectors in the European Union. However, there remains large disparities in per capita energy consumption levels across regions and sectors (see table A.6 in appendix A).

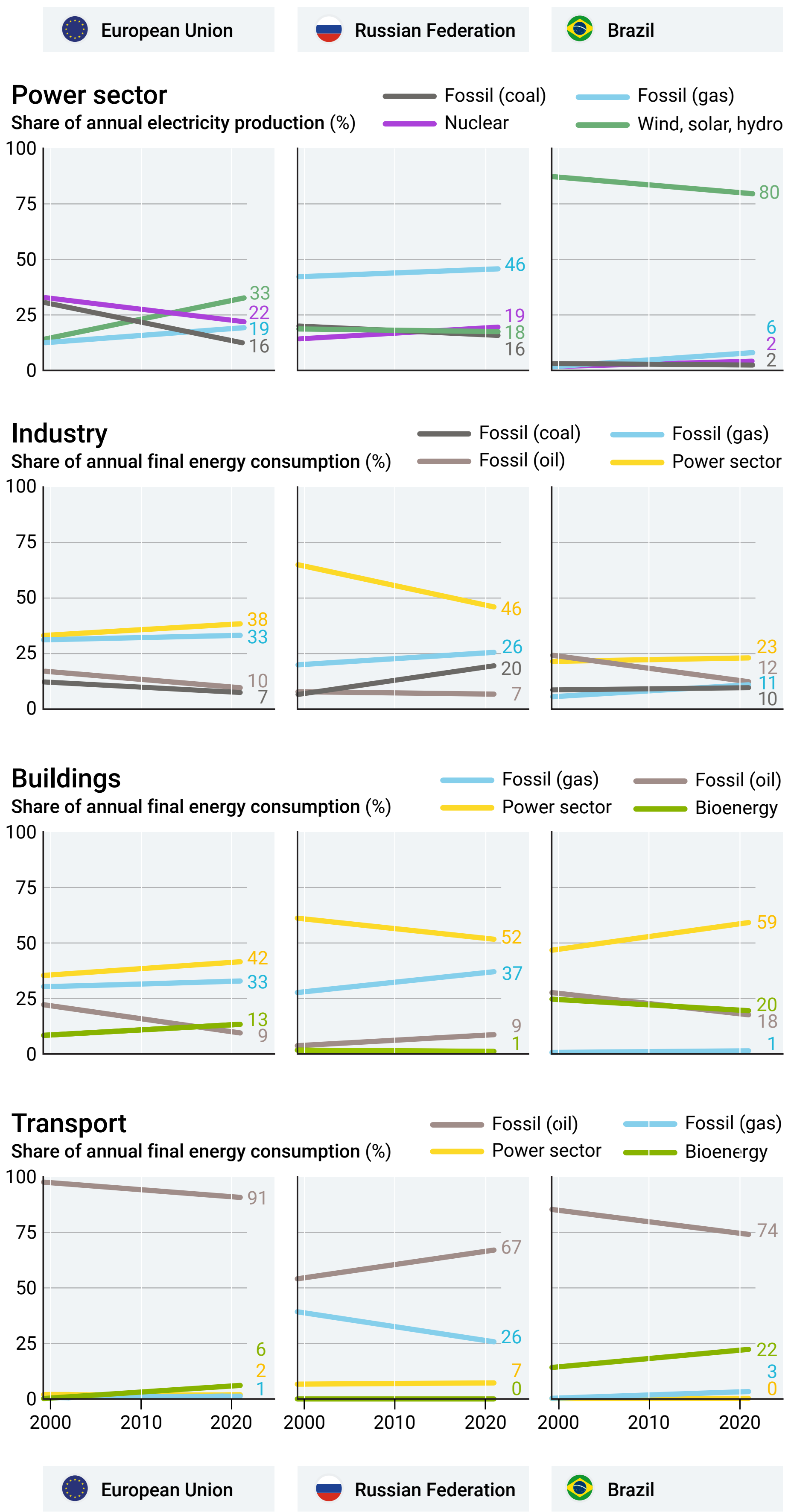
Underlying these activity levels are trends in final demand for goods and services (such as food and water, mobility needs, demand for capital and infrastructure goods) and access to home energy services (such as heating, cooling, lighting and refrigeration). However, there are significant interregional differences, and growth in certain activities in developing regions is desirable and necessary to improve access to basic services and decent living standards.

Countering some of the growth on the activity side have been improvements in efficiency (using less energy to perform an activity), structural change (shifts in economic structure or technologies used, e.g. to service-based economies) and changes in carbon intensity (shifts towards lower carbon fuels or non-fossil sources) (Bersalli, Tröndle and Lilliestam 2023). Historically, global energy intensity (energy use per unit of gross domestic product) has progressively declined, while carbon intensities have started to decline since 2013 (Friedlingstein *et al.* 2023). However, these improvements have so far not been sufficient to offset growth in activity, at least at a global level, leading to overall increases in emissions. For example, globally, there is a longer term shift towards higher per capita electricity use, larger building floor areas (+60 per cent increase in the past two decades), more global manufacturing value added (32 per cent from 2009–2019), larger passenger vehicles (sports utility vehicles had nearly half of total car sales in 2023) and more air travel (International Air Transport Association 2023; IEA 2023; IEA 2024c).

Considering aviation, between 1990 and 2021, the emissions intensity of the sector fell, but only due to a decline in the energy intensity of aviation by 60 per cent, while carbon intensity remained unchanged due to continued reliance on fossil-based fuels. Between 1990 and 2021, passenger demand tripled and freight demand grew four times, driving up emissions significantly (Bergero *et al.* 2023). An increasing number of policies and initiatives have been established to enhance the share of sustainable aviation fuels that are produced from non-fossil sources such as biomass and waste (IEA 2024d). However, it is unlikely that ambitious climate targets can be achieved in the sector without managing levels of demand (Bergero *et al.* 2023).

Figure 2.3 Share of fossil and non-fossil energy sources by sector globally and for major emitters





Note: Shares do not sum to 100 per cent for all countries and categories, as not all energy sources are shown. Only energy-related sectors (see figure 2.2) are shown. Values for the power sector are reported up to 2022 and all other sectors are reported up to 2021.

Source: Wiatros-Motyka *et al.* (2024); IEA (2024e).

Coal, oil and gas continue to dominate energy systems globally (figure 2.3). Yet, fossil shares are starting to decrease in the power sector as solar and wind power production rapidly grows, with global annual renewable energy capacity additions increasing by 50 per cent in 2023 (IEA 2024f). Global clean energy investment is growing rapidly as the spending on renewable power, grids and storage is now higher than total spending on oil, gas and coal. However, there are variations across regions and countries (IEA 2024d). In 2022, fossil sources accounted for 61 per cent of global electricity generation, a decrease of 4 percentage points from five years prior (Wiatros-Motyka *et al.* 2024). Regional changes have been more dramatic, with absolute reductions in coal power production in the United States of America and Europe, and a rapidly declining relative share in China (figure 2.3). However, gas power production is still growing in the United States of America as well as globally. Eleven countries already achieved over 30 per cent of annual electricity production with wind and solar power in 2022. There are signs that power sector emissions may soon reach a peak as the majority of new global electricity demand is projected to be met by renewable sources (Wiatros-Motyka *et al.* 2024) (see box 4.1). Yet despite these trends, power sector emissions grew by 1.6 per cent in 2023 and there remains a gap in policy implementation (chapter 3). There is a growing commitment to accelerate the phase out of unabated fossil fuels. However, none of the major fossil fuel-producing countries or companies have committed to phasing out these activities to fully transition away from fossil fuel extraction or production (Net Zero Tracker 2023).

Coal, oil and gas still account for 57 per cent of direct final energy consumption in the industry sector, 36 per cent in the buildings sector and 95 per cent in the transport sector in 2021 (figure 2.3) (IEA 2024e). The electrification of these end-use sectors is an important strategy to improve efficiency and leverage rapid shifts to renewable sources in the power sector. With the exception of China, which has rapidly electrified the industry and buildings sectors, progress on this front has generally been slow, especially in transport. Overall, the power sector share of final energy consumption for end-use sectors remains at or well below 50 per cent in most countries and regions. Further, there has been very slow progress in the past five years, suggesting that policy or technical bottlenecks still need to be overcome.

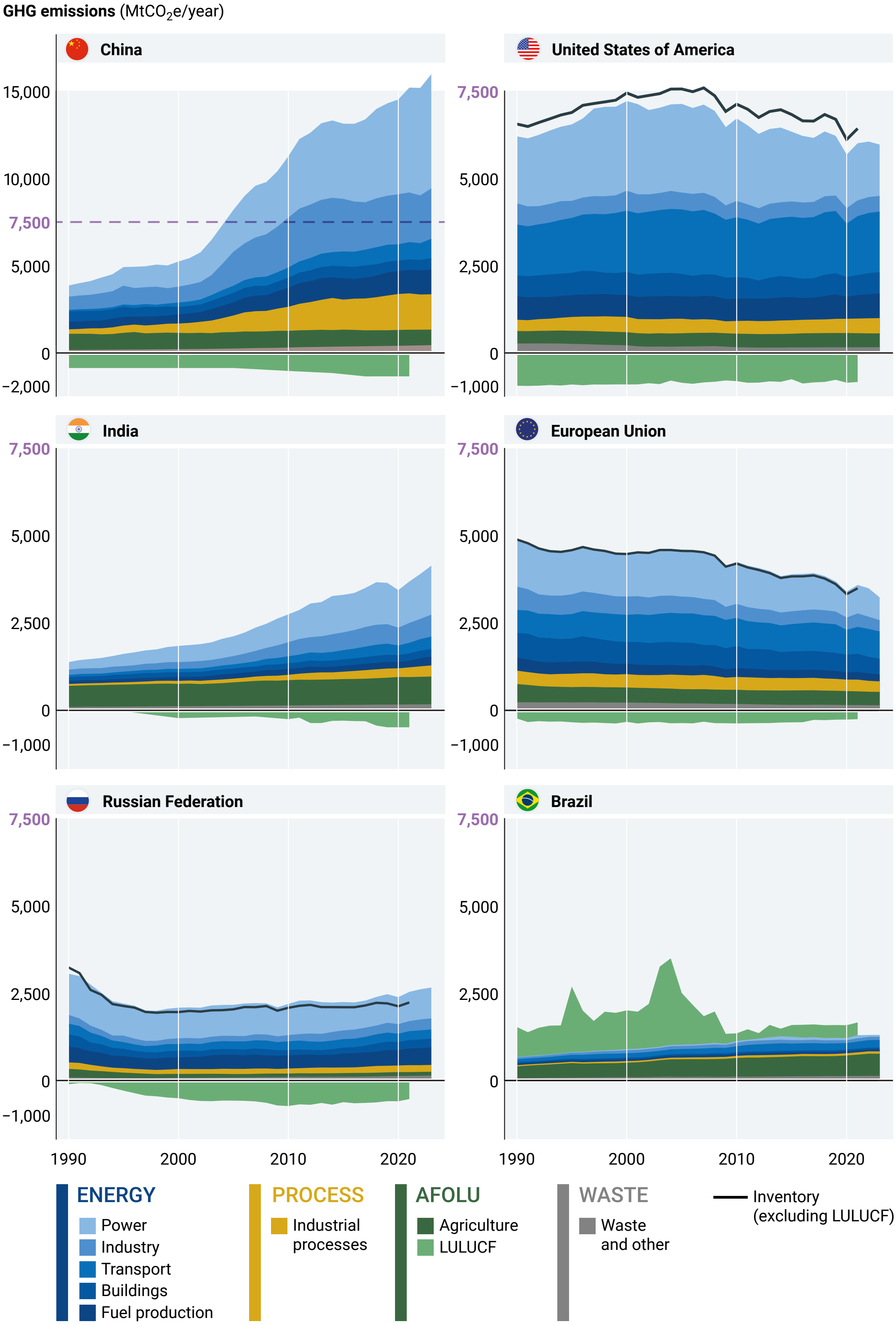
Climate and energy policies are an important driver of current and historic emissions, but their effects remain challenging to quantify. A recent global study of 1,500 climate policies concluded that successful policy interventions may have reduced emissions by 0.6 $GtCO_2$ to 1.8 $GtCO_2$ compared with a no-action scenario. Policy instruments included carbon pricing, subsidies, building codes, energy efficiency mandates and standards. Several of these policy instruments had higher effects when they were part of a policy mix rather than as stand-alone measures (Stechemesser *et al.* 2024). Hoppe *et al.* (2023) concluded that implementation of mitigation policies since 1990 resulted in a reduction of several $GtCO_2e$ per year compared with a no-action scenario. Policies supporting research and development had a higher positive impact at the early stages for technology diffusion, while feed-in tariffs, tax incentives and subsidies have been effective in increasing the share of renewable energy generation. Regulatory instruments (such as vehicle fuel economy standards, emission standards and building sector regulations) have been effective in reducing energy use in the buildings and transport sectors, while mandatory energy audits and support for renewable energy have shown positive results for the industry sector.

2.4 Emissions of the G20 increased overall in 2023 and accounted for 77 per cent of the total

Currently, the six largest emitters globally are China, the United States of America, India, the European Union, the Russian Federation and Brazil (figure 2.4).[2] Preliminary estimates for 2023 (which exclude LULUCF CO_2 for which data is only available up to 2021) show an increase in GHG emissions compared with 2022 in China, India and the Russian Federation, and a decrease in the European Union and the United States of America (table 2.2). GHG emissions in Brazil remained steady in 2023.

2 In terms of total GHG emissions in 2023, excluding LULUCF CO_2.

Figure 2.4 GHG emissions of the six largest GHG emitters



Note: Emissions are calculated on a territorial basis. LULUCF CO_2 emissions and removals are here based on the inventory approach. See table A.4 in appendix A for a description of the sectors. Note that GHG emissions presented here (with the exception of LULUCF CO_2) are based on third-party sources (see appendix A), but a comparison to the latest available (Annex I) inventory estimates is depicted in black.

Source: Crippa *et al.* (2024); Grassi *et al.* (2022).

The G20 members accounted for 77 per cent of global GHG emissions in 2023, excluding the African Union, which joined that year (table 2.2). If all African Union members are added to the G20 total, more than doubling the number of members from 44 to 99, total emissions increase by just 5 percentage points to 82 per cent.[3] Least developed countries (LDCs) – which include many African Union members – remain a minor contributor to global emissions at 3 per cent of the total.

Net LULUCF CO_2 emissions, especially from deforestation and land-use change, continue to be concentrated in tropical regions, with Brazil, Indonesia and the Democratic Republic of the Congo contributing 55 per cent of the global total (bookkeeping-based) in 2022. Countries that have a higher contribution from LULUCF CO_2 also tend to experience larger annual fluctuations in GHG emissions due to policy-induced land-use changes, deforestation, wildfires on managed land or shifts towards forest protection (figure 2.4). In other countries and world regions, net LULUCF CO_2 removals from afforestation, reforestation and forest management have been reported in the past decades. This includes the United States of America, India, the European Union and the Russian Federation (figure 2.4).

Despite significant changes in the past 20 years, there continue to be large disparities between the current, per capita and historic emissions of the largest emitters and world regions. Per capita GHG emissions are significantly above the world average of 6.6 tons of CO_2 equivalent in the United States of America and the Russian Federation, and remain significantly below it in India, the African Union and in LDCs (table 2.2). In terms of historic cumulative CO_2 emissions (including LULUCF), the United States of America has produced the most global CO_2 emissions to date, followed by the European Union and China. By contrast, India, LDCs and the African Union have only produced a minor share of historic cumulative emissions (table 2.2), despite being highly populous countries and regions. As discussed in last year's Emissions Gap Report (UNEP 2023), a consistent finding in the literature is that households with the highest income or wealth contribute a disproportionate share of emissions worldwide. These households are also concentrated in wealthier countries.

Table 2.2 Total, per capita and historic emissions of selected countries and regions

	Total GHG emissions in 2023	Change in total GHG emissions, 2022–2023	Per capita GHG emissions in 2023	Historic CO_2 emissions, 1850–2022
	$MtCO_2e$ (% of total)	%	tCO_2e/capita	$GtCO_2$ (% of total)
China	16,000 (30)	+5.2	11	300 (12)
United States of America	5,970 (11)	-1.4	18	527 (20)
India	4,140 (8)	+6.1	2.9	83 (3)
European Union (27 members)	3,230 (6)	-7.5	7.3	301 (12)
Russian Federation	2,660 (5)	+2	19	180 (7)
Brazil	1,300 (2)	+0.1	6.0	119 (5)
African Union (55 members)	3,190 (6)	+0.7	2.2	174 (7)
Least developed countries (45 countries)	1,720 (3)	+1.2	1.5	114 (4)
G20 (excl. African Union)	40,900 (77)	+1.8	8.3	1,990 (77)

Note: Emissions are calculated on a territorial basis. LULUCF CO_2 emissions are excluded from current and per capita GHG emissions, but are included in historic CO_2 emissions based on the bookkeeping approach. Note that GHG emissions presented here are based on third-party sources (see appendix A), but a comparison to the latest available (Annex I) inventory estimates is available in figure 2.5. Some members of the African Union are also LDCs.

Source: Crippa *et al.* (2024); Friedlingstein *et al.* (2023).

3 The African Union consists of 54 United Nations Member States and the Non-Self-Governing Territory of Western Sahara, which has been admitted to the African Union as the Sahrawi Arab Democratic Republic.

3 Nationally determined contributions and long-term pledges: The global landscape and G20 member progress

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3.1 Introduction

The architects of the Paris Agreement envisioned that parties would ratchet up the ambition of their mitigation efforts to close the emissions gap. Three key milestones will put that vision to a critical test over the coming months. First, by November 2024, parties are encouraged to communicate or revise long-term low-emission development strategies "towards just transitions to net-zero emissions by or around mid-century." Next, by the end of 2024, parties are to submit their first biennial transparency reports, which will outline their progress towards their nationally determined contributions (NDCs). Finally, by February 2025, parties are to communicate new NDCs containing targets and measures for 2035. The first global stocktake, which concluded in 2023, guides parties in developing their NDCs. The achievement of the Paris Agreement goals hinges on the extent to which parties leverage this moment to chart out a new, transformative path.

This chapter takes stock of the current state of play of long-term pledges and NDCs, as well as the domestic policies that support their implementation. The chapter is structured as follows. Section 3.2 assesses global progress on NDCs since the Paris Agreement was adopted. Section 3.3 examines G20 progress towards NDC targets. The section quantifies the implementation gap, which is defined as the difference between "a country's future emissions under the target and those under its current policies" (Fransen *et al.* 2023; see also den Elzen *et al.* 2019), by synthesizing emission scenarios from the literature. Section 3.4 assesses global and G20 progress on net-zero targets and long-term pledges, including the implication of NDCs for G20 members' progress towards these targets. In addition to individual countries, the G20 includes the African Union and the European Union. Because the African Union has neither a collective NDC nor a net-zero target, the assessment does not include commitments by the African Union as a whole. (The commitments of South Africa, a member of both the African Union and the G20, are assessed.) The European

Union has both a collective NDC and a net-zero target, so these are included in the assessment alongside those of the European Union and G20 members France, Germany and Italy. The methodology and preliminary findings of this chapter were made available to the governments of the G20 members to provide them with the opportunity to comment on the findings.

The cut-off date for the literature and data assessed in this chapter is 1 June 2024 except where otherwise noted. Country-level emissions represent territorial emissions unless otherwise noted. Greenhouse gas (GHG) emissions are expressed using the 100-year global warming potentials from the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In contrast to chapter 2, this chapter uses the latest national GHG inventories as compiled by Nascimento *et al.* (2024a) for historical energy and industry emissions, supplemented by the harmonized national GHG inventories-based data set for historical carbon dioxide (CO_2) emissions from land use, land-use change and forestry (LULUCF) (Grassi *et al.* 2023). These methodological choices cause minor variation in country-level emissions estimates across chapters 2 and 3.

3.2 Global trends in current NDCs provide important guidance for the next NDCs

NDCs are the foundation of the Paris Agreement. They are the commitments that countries pursue measures towards achieving, and against which they report their progress. Submitted every five years, each NDC must "represent a progression" beyond the last and reflect each party's "highest possible ambition" and "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." As described in chapter 1, the next NDCs are to be informed by the outcome of the first global stocktake, which called on parties to align their NDCs with 1.5°C and with long-term low-emission development strategies "towards just transitions to net zero", and to set out sector-specific global mitigation efforts to which it encouraged parties to contribute "in a nationally determined manner." It noted the need for enhanced support and investment. The Emissions Gap Report tracks the number of countries communicating new or updated NDCs, the impact of these updates on emissions, and key characteristics related to the emission reduction targets included in these NDCs (table 3.1).

While the decision of the twenty-eighth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 28) – like the decisions of the two COPs before it – requested countries to revisit and strengthen their 2030 targets, only three countries (Madagascar, Namibia and Panama) submitted new or updated NDCs by 1 September 2024, and only Madagascar strengthened its 2030 target (Climate Watch 2024a). These submissions bring the total number of Paris Agreement parties that have replaced or updated their original NDCs to 151 (counting the European Union and its 27 Member States as a single party) out of 168 total NDCs. The current unconditional NDCs, if fully implemented, would reduce global 2030 GHG emissions by about 5.0 gigatons of CO_2 equivalent ($GtCO_2e$) (range: 2.2–8.0 $GtCO_2e$) compared with the initial NDCs, or 5.3 $GtCO_2e$ (range: 2.7–8.0 $GtCO_2e$) if conditional NDCs are also counted.[1] These estimates are similar to last year's because the NDC updates since then are quite minor.

Relative to the initial NDCs, more NDCs now contain GHG reduction targets, and more targets (though still a minority) are absolute reduction targets relative to a base year. Second, a majority of these targets are now economy-wide – that is, they cover a country's entire economy as opposed to certain parts of it. While few NDCs cover all GHGs, a majority cover the three main gases (CO_2, methane and nitrous oxide). This is notable in light of the outcome of the first global stocktake, which encouraged parties to submit "ambitious, economy-wide emission reduction targets, covering all GHGs, sectors and categories and aligned with limiting global warming to 1.5°C, as informed by the latest science, in the light of different national circumstances."[2]

1 The data come from three model groups with updated NDCs, with the literature cut-off date of 1 June 2024 (Keramidas *et al.* 2023; Meinshausen *et al.* 2023; Nascimento *et al.* 2023), and two open-source tools (Climate Action Tracker 2024b; Fransen *et al.* 2022 as updated using Climate Watch 2024a).

2 The Paris Agreement stipulated that developed country NDCs are to have economy-wide, absolute emission reduction targets, while developing countries are to move over time towards economy-wide targets.

Table 3.1 Evolution of NDC characteristics since the adoption of the Paris Agreement at COP 21

NDC characteristics	COP 21 (2015)	COP 26 (2021)	COP 27 (2022)	COP 28 (2023)	EGR 2024
Number of NDCs:	Number of NDCs (% of global emissions incl. LULUCF)				
That reduce 2030 emissions relative to initial NDCs	N/A	65 (63%)	79 (79%)	82 (80%)	83 (80%)
That contain a GHG reduction target	122 (85%)	143 (89%)	147 (91%)	148 (91%)	148 (91%)
That contain a GHG reduction target relative to a base year	35 (33%)	43 (34%)	44 (34%)	46 (35%)	46 (35%)
That contain a GHG reduction target relative to a baseline scenario	74 (19%)	84 (19%)	87 (21%)	87 (20%)	87 (20%)
That contain a GHG intensity target	7 (32%)	7 (33%)	7 (33%)	5 (32%)	5 (32%)
Target coverage					
That contain a GHG target covering all sectors (energy; industry; waste; LULUCF)	46 (44%)	80 (53%)	85 (55%)	88 (55%)	89 (55%)
That contain a GHG target covering at least CO_2, methane and nitrous oxide	99 (53%)	125 (57%)	130 (58%)	132 (58%)	132 (58%)
That contain a GHG target covering all GHGs listed in the Kyoto Protocol (CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride)	20 (29%)	22 (30%)	23 (31%)	23 (31%)	23 (31%)
Conditionality					
That are fully conditional	45 (12%)	34 (12%)	32 (12%)	33 (12%)	35 (12%)
That are fully unconditional	30 (58%)	36 (62%)	34 (62%)	34 (61%)	34 (61%)
That contain both conditional and unconditional elements	78 (20%)	96 (21%)	101 (21%)	101 (21%)	99 (21%)

Note: Some NDCs contain more than one type of GHG target.

The Paris Agreement stipulates that the global stocktake "shall inform Parties in updating and enhancing their actions and support," including NDCs. The first global stocktake concluded in 2023. It "calls on Parties to contribute…in a nationally determined manner" to a range of sector-specific "global efforts" as outlined in paragraph 28. These objectives, and the number of current NDCs that contain targets and other measures related to them, are presented in table 3.2. This analysis considers the relevance of NDCs, but not their adequacy, vis-à-vis the global efforts. For instance, for the global effort to triple renewable energy capacity by 2030, any NDC containing a target or measure related to renewable energy capacity is counted. The analysis does not, however, assess whether the renewable measures in each NDC or the NDCs collectively are strong enough to triple renewable capacity globally.

While the substantial majority of NDCs contain measures relevant to promoting renewable energy and energy efficiency, a far smaller share explicitly address efforts towards the phase-down of unabated coal and transitioning away from fossil fuels.

Table 3.2 **Number of NDCs containing measures related to global stocktake outcome**

Global effort (paragraph of global stocktake outcome)	Number of NDCs containing related measures (Climate Watch 2024a)
Tripling renewable energy capacity by 2030 (28a)	152
Doubling global average annual rate of energy efficiency improvements by 2030 (28a)	142
Accelerating efforts towards the phase-down of unabated coal power (28b)	42
Accelerating efforts globally towards net-zero emission energy systems (28c)	151
Transitioning away from fossil fuels in energy systems (28d)	27
Accelerating zero- and low-emission technologies, including, inter alia, renewables, nuclear, abatement and removal technologies (28e)	151
Accelerating the substantial reduction of non-CO_2 emissions globally (28f)	83
Accelerating the reduction of emissions from road transport (28g)	139
Phasing out inefficient fossil fuel subsidies (28h)	Data not available
Conserving, protecting and restoring nature and ecosystems towards achieving the Paris Agreement temperature goal, including through enhanced efforts towards halting and reversing deforestation and forest degradation by 2030, and other terrestrial and marine ecosystems acting as sinks and reservoirs of GHGs (33)	116

The implications of this analysis for the next round of NDCs are as follows. First, repeated COP requests for countries to strengthen their 2030 targets have ceased to deliver meaningful progress, yet it is necessary to do better than the existing 2030 NDC targets to maintain the possibility of limiting global warming to 1.5°C (see chapter 4). The preparation of the next NDCs offers an opportunity to consider how to strengthen policy implementation in response to the outcome of the global stocktake. Ideally, this would both enable more ambitious 2035 targets and result in overachieving the 2030 targets, i.e. bringing emissions below the current NDC targets, regardless of whether the latter are formally strengthened. Second, while the scope and coverage of NDC targets have increased since COP 21, only 55 per cent of global emissions are covered by economy-wide targets. The next round of NDCs offers an opportunity to enhance target coverage, as was highlighted in the outcome of the global stocktake. Finally, while current NDCs contain measures relevant to many of the global efforts identified in the outcome of the global stocktake, it is not yet clear in most cases that these measures are strong enough to achieve the stated goals. Moreover, some of the global efforts, such as transitioning away from fossil fuels, are not explicitly reflected in most NDCs. The next round of NDCs therefore represents an opportunity for countries to more thoroughly consider and transparently account for their contributions to these global efforts.

3.3 Progress of G20 economies towards NDCs has stalled

This section assesses the collective and individual progress of G20 members towards achieving their 2030 NDC targets, thereby bridging the NDC implementation gap. Box 3.1 summarizes the analytical methods applied for the assessment. The assessment is based on emission scenarios that quantify the anticipated emission reduction impact of adopted policies.

Compared with the 2023 report, the data set incorporates updates from annually published studies (Keramidas *et al.* 2023; Nascimento *et al.* 2023; Climate Action Tracker 2024 ; see appendix B3, available online, for the list of studies considered in the assessment). The African Union is not assessed as it does not have an organization-wide emission reduction target like the European Union. The assessment of emissions projections is accompanied by consideration of recent major policy developments that are not yet fully reflected in emissions projection studies (appendix B).

While this section assesses the adequacy of each G20 member's implementation efforts against its own NDC targets, it does not evaluate the adequacy of individual G20 members' implementation efforts relative to the climate goal of the Paris Agreement (see chapter 5). Such an assessment depends on important underlying assumptions about space, time and equity, on which there is no consensus (Lecocq and Winkler 2024). The literature on "burden-sharing" and "fair shares" that presents countries' reduction targets based on equity-based effort-sharing approaches (Pan *et al.* 2017; Robiou du Pont *et al.* 2017; Robiou du Pont and Meinshausen 2018; van den Berg *et al.* 2020) is disputed (e.g. Dooley *et al.* 2021), and countries themselves take a range of approaches (Winkler *et al.* 2018) (see also chapter 5). Some fairness indicators proposed by national governments or in the literature are incompatible with the equity principles of international environmental law (Rajamani *et al.* 2021).

Box 3.1 Methodology underlying the assessment of G20 member progress

The updated assessment of progress towards 2030 targets is based on a synthesis of emissions projection studies by independent research groups. The studies considered in the assessment are mostly published between 2022 and 1 June 2024. A list of the studies as well as the criteria for their inclusion is available in appendix B.2. In line with previous Emissions Gap Reports, the assessment follows the methodology of den Elzen *et al.* (2019). NDC targets are compared with emission projections under a current policies scenario, which reflects all policies adopted and implemented up to specific cut-off dates, and which for this report are defined as legislative decisions, executive orders or their equivalent. This implies that officially announced plans or strategies alone would not qualify, while individual executive orders to implement such plans or strategies would qualify. Policies that are adopted most recently, some of which are presented in section 3.3.3, may not be considered in the scenario studies reviewed, as they were prepared before their adoption.

To evaluate the conditionality of NDCs, the categorization of World Resources Institute was adapted (Climate Watch 2022): India, Indonesia and Mexico have both unconditional and conditional NDCs, while South Africa only has a conditional NDC, which is included in the G20 aggregate of unconditional NDCs.

The assessment based on independent studies is also compared with official projections published by national governments. Many of the "With existing measures" scenario projections in the latest United Nations Framework Convention on Climate Change submissions are considered as current policies scenario projections. Methodological limitations of the assessment are similar to those described in previous Emissions Gap Reports. The assessment is based on 'point in time' emissions projections for the NDC target year,[3] and on emissions including LULUCF.

3.3.1 2030 NDC implementation status

Collectively, the G20 members are projected to emit 34 $GtCO_2e$ in 2030 under unconditional NDCs (central estimate) and 35 $GtCO_2e$ (central estimate) under the current policies scenario (see box 3.1 and appendix B). This is identical to 2019 levels and exceeds the unconditional NDCs by 1 $GtCO_2e$. The current policies scenario projections for 2030 fall slightly compared with last year's report but so do the unconditional NDC scenario projections, mainly due to China's and India's NDCs, both of which have relative target components. Therefore, the implementation gap for unconditional NDCs remains similar to last year's assessment (see country-specific emissions projections and their literature range in appendix B.5, figure B-1). The results strongly suggest that the adoption and effective implementation of additional and/or more stringent policies across countries and sectors are required for achieving the unconditional NDCs.

Projections under current policies are lower than last year's assessment for eleven G20 economies, including China, India and the United States of America, while these reductions were partly offset by increased projections in the remaining six G20 economies.[4] The most notable among the latter six is Indonesia. Its 2030 current policies scenario projections increased by 0.3 $GtCO_2e$ due to previously unreported emissions from "captive" coal power plants (i.e. off-grid power plants to power industrial facilities directly) as assessed by Climate Action Tracker and revised LULUCF emissions projections by the Joint Research Centre.

The progress of individual G20 members towards their latest unconditional NDC targets is shown in more detail in figure 3.1, organized by the likelihood of achieving the targets with existing policies. Overall, eleven G20 members are assessed to be falling short of achieving their NDC targets with existing policies. Besides Indonesia for the reasons described above, Saudi Arabia is also assessed this year to be less likely to achieve its NDC mainly due to the revised estimates of the updated NDC in the literature after more information became available on the assumed baselines. The European Union is now assessed to be on track to meet its NDC as more studies quantify the likely impact of recent policies including the Fit for 55 package and the REPowerEU plan.

Several G20 members that have been projected to meet their NDC target based on current policies are those that did not strengthen, or only moderately strengthened, their target levels in their new or updated NDCs (section 3.2.1; den Elzen *et al.* 2022; Nascimento *et al.* 2024b). For three G20 members, the projected emissions under their current

3 Some countries also set an emissions budget for a multi-year period; an assessment of these targets may lead to different conclusions.

4 Seventeen G20 economies are analysed here, counting the European Union as one.

policies are considerably below unconditional NDC target levels ever since these targets were submitted, thereby artificially lowering the implementation gap. If unconditional NDC projections are replaced by current policies projections for these members, then the G20 members' collective implementation gap increases to 1.9 $GtCO_2e$.

Figure 3.1 Assessment of progress towards achieving the current NDC targets

LIKELY to meet the target with existing policies*

Country	Number of studies
China	●●●●●○
European Union	●●○ [1)]
India	●●●●
Türkiye	●●●
Russian Federation	●●●○ [1)]
Mexico	●●

LESS LIKELY to meet the target with existing policies

Country	Number of studies
Argentina	○○○
Australia	○○○ [1)]
Brazil	○○○
Canada	○○○○ [1)]
Indonesia	○○○
Japan	○○○
Republic of Korea	●○○
Saudi Arabia	○○
South Africa (Conditional NDC)	●○○
United Kingdom	○○ [1)]
United States of America	○○○○○○○ [1)]

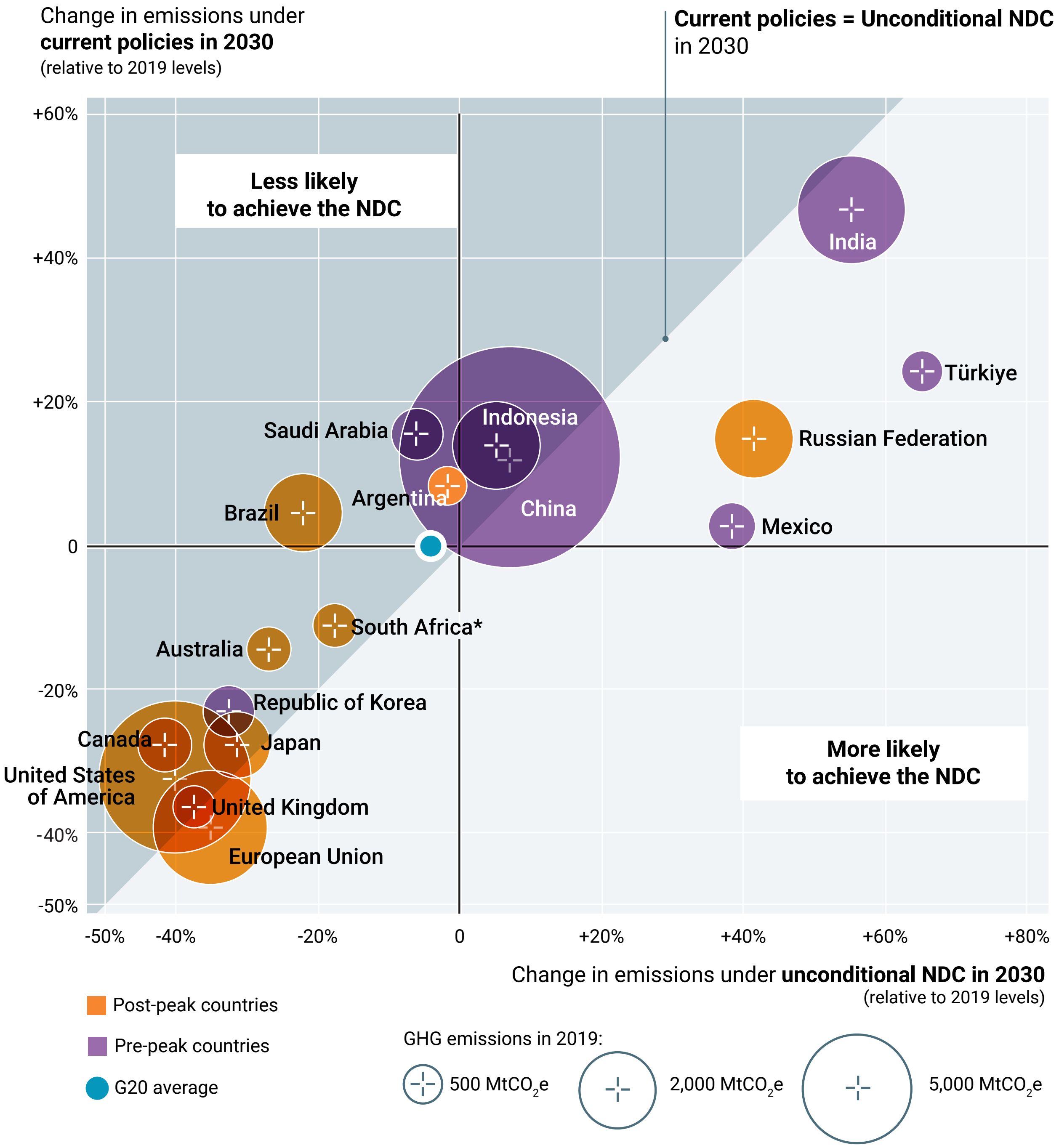
Number of studies indicating: ● Target will be achieved ○ Target will be missed | Conditional NDC (grey shading) | **Bold font:** overachieved by more than 15%

Note: All NDCs considered in this assessment are unconditional NDCs, unless otherwise mentioned. The African Union does not have its organization-wide NDC as at 1 June 2024. The assessment is based on independent studies mainly published in 2022 or later (see appendix B2 for the list of studies reviewed). The number of independent studies that project a country to meet its current NDC target are compared with the total number of studies and indicated in brackets.

[1)] Current policies scenario projections from official publications are also examined. The official publications for five G20 members (Australia, Canada, European Union, United Kingdom and United States of America) show that they do not project yet to meet their 'point in time' NDC target under their current policies scenarios (Australia, Department of Climate Change, Energy, the Environment and Water 2024; European Environment Agency 2023; Environment and Climate Change Canada 2023; Capros *et al.* 2021; United Nations Framework Convention on Climate Change 2024); for the Russian Federation, official projections of the Fifth Biennial Report indicate that the country would achieve its NDC with existing policies (Russian Federation 2023). For the European Union, the official projections by the European Environment Agency do not fully account for the impact of some recently adopted policies, most notably the REPowerEU plan.

The conditional NDCs of India, Indonesia and Mexico would lower the G20 aggregate emissions by roughly 0.8 $GtCO_2e$ per year in 2030. India and Mexico are projected to meet their conditional NDCs (4 of 4 studies and 2 of 3 studies, respectively). Across G20 members, there is a wide variation in implementation gaps as well as the projected emissions in 2030 relative to 2019 levels as shown in figure 3.2. Where values along the diagonal imply no implementation gap, values below the diagonal indicate that countries are more likely to achieve their NDC, and values above the diagonal reflect that achievement of current NDC targets are less likely based on existing policies. The figure also illustrates that, collectively, the G20 targets in 2030 remain far from the average global percentage reductions required to align with 2°C and 1.5°C scenarios (see chapter 4).

Figure 3.2 The landscape of current NDC targets and implementation gaps for the G20 members collectively and individually by 2030, relative to 2019 emissions



Note: Except for South Africa (denoted by an asterisk), the figure includes unconditional NDC pledges. G20 members below the diagonal line suggest they are likely to meet their NDC based on existing policies. The G20 average is shown without an indication of the size of GHG emissions in 2019.

3.3.2 Per capita emissions

To supplement the above findings and complement chapter 2, figure 3.3 presents per capita GHG emissions in 2019 and projections for 2030 under the NDC and current policies scenarios. Overall, there are limited changes compared with 2023; the average per capita emissions in 2030 of G20 members under the latest NDCs are projected to be only marginally lower (6.8 tCO_2e) than under the current policies scenario (7.0 tCO_2e).

Echoing the findings of chapter 2, figure 3.3 shows that per capita emissions range widely across G20 members. Projected trends between 2019 and 2030 are considerably different between G20 members whose emissions have peaked and those whose emissions have not yet peaked (see section 3.4.3 for further discussion). Per capita emissions are projected to decrease considerably by 2030 for most G20 members whose emissions have peaked, while the trends across G20 members whose emissions have not yet peaked are most diverse, in part depending on their stage of economic circumstances. However, per capita emissions in 2030 are projected to remain considerably higher than the global average 1.5°C-aligned levels for nearly all G20 members both under current policies and NDC scenarios. For several G20 members, the emission levels in 2030 would remain three times higher than the global 1.5°C-aligned levels.

3.3.3 Developments in domestic policy

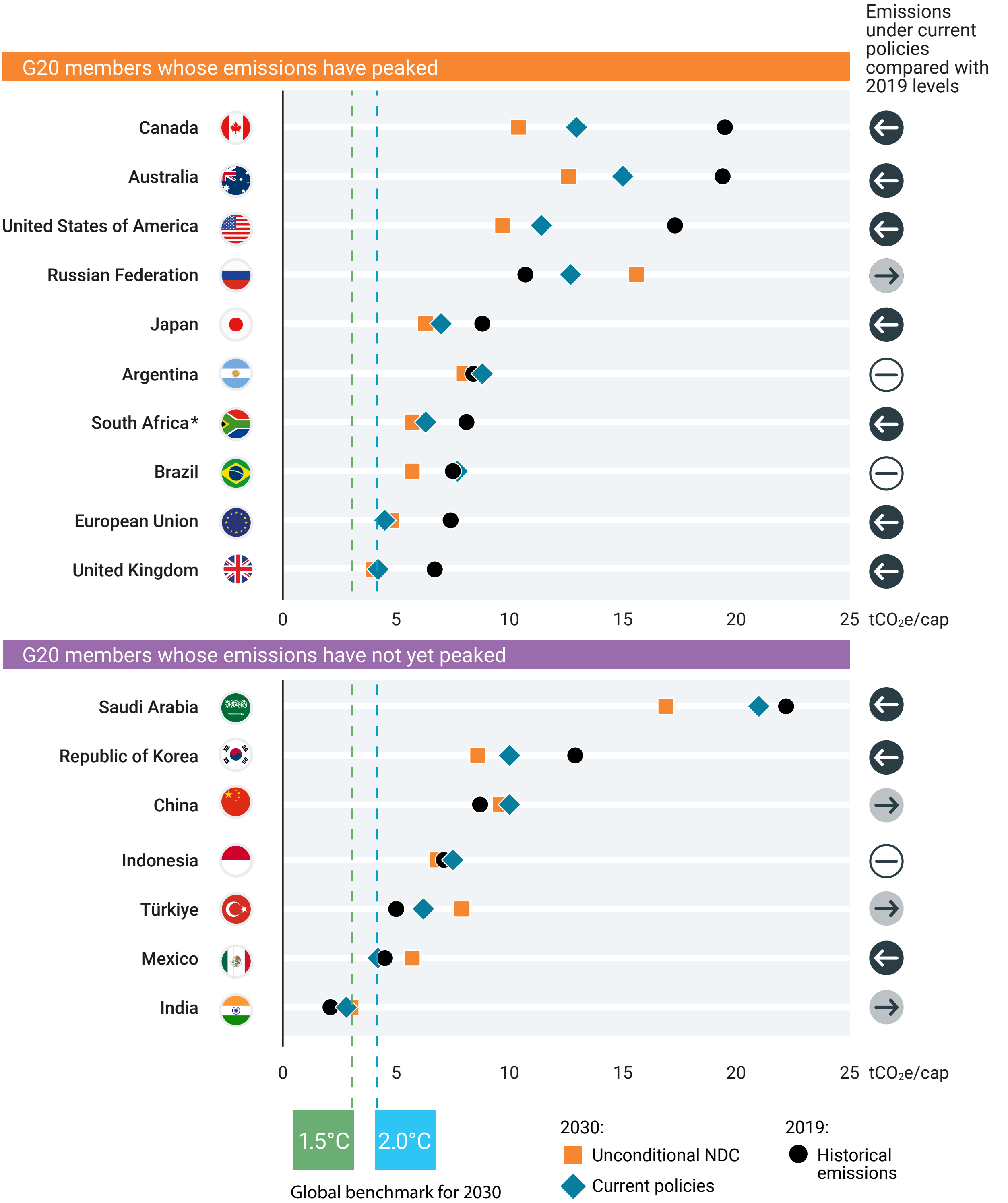
The projections in section 3.3.2 do not include the most recent policy developments, since most are not yet reflected in the models. In line with previous editions of this report, a systematic review of recent policy updates (mid-2023 to mid-2024) of the G20 was therefore conducted, to identify specific policies that may affect future GHG emission trajectories. The review focused on policies that are quantified or analysed to have positive or negative effects in reducing global or national implementation gaps in recent studies. The review started from the peer-reviewed literature (Nascimento *et al.* 2024c), followed by the assessments by national policy experts in respective G20 members, and inputs from the national governments across the review process.

The review indicates that, while climate policy has advanced in many G20 members, there is still a lack of studies evaluating their effects on emissions towards 2030. Therefore, it has not been possible to assess whether the policies that the G20 members adopted since last year's assessment are projected to have significant effects on global emissions in 2030.

The review also found that, in some cases, the effect of recent climate policies may be partially cancelled out by contradicting policies or developments within or outside G20 members' respective borders (e.g. Nascimento *et al.* 2024c).

Appendix B provides a non-exhaustive overview of these recent policy updates for selected G20 members. While the overview was developed systematically as described above, it is acknowledged that policies not covered, including those not directly driven by climate motivation, may still result in substantial emission reductions and support the implementation of more stringent policies over time.

Figure 3.3 G20 member per capita emissions (including LULUCF) implied by current policies and unconditional NDCs, compared with 1.5°C-consistent global average levels



Note: For G20 members where the difference in per capita emissions between current policies and 2019 levels is less than +/-5 per cent, a flat line rather than an arrow is used to indicate no significant change. i) The conditional NDC was considered for South Africa; ii) for 2030 projections, see appendix B3 for data sources. Central estimates are the median values when five or more studies were available, otherwise they are average values, following the approach in den Elzen *et al.* (2019); iii) data on historical and projected (medium fertility variant) population per country are taken from the United Nations World Population Prospects 2024 (Department of Economic and Social Affairs, Population Division 2024); iv) historical emission data for 2019 were compiled from the latest national GHG inventories (Nascimento *et al.* 2024a) for energy and industry emissions, and Grassi *et al.* (2023) for LULUCF based on national inventories; v) to estimate G20 total emissions for the NDC pledges scenario, emissions projections under the current policies scenario were used for India, the Russian Federation and Türkiye; vi) The global average 1.5°C benchmark (>50 per cent chance, no or low overshoot) is calculated based on the findings from chapter 4 of this report; the emissions estimates from the integrated assessment models are offset by 6 $GtCO_2e$ throughout the assessment period (2019–2030) to adjust for the differences in land use emissions accounting.

3.4 Developments in long-term and net-zero pledges show reasons for concern

3.4.1 Global developments in long-term and net-zero pledges

As at 1 September 2024, 101 parties representing 107 countries and covering approximately 82 per cent of global GHG emissions had adopted net-zero pledges either in law (28 parties), in a policy document such as an NDC or a long-term strategy (56 parties), or in an announcement by a high-level government official (17 parties).[5] Since the Emissions Gap Report 2023, only Romania has added a net-zero target. An additional twelve parties covering an additional 2 per cent of global GHG emissions have another (non-net-zero) GHG mitigation target as part of their long-term strategy. A total of 37 per cent of 2019 global GHG emissions are covered by net-zero targets for 2050 or earlier, while 45 per cent of global emissions are covered by net-zero pledges for years later than 2050. Five parties, representing 0.1 per cent of global emissions, report they have already achieved net-zero emissions and have explicitly committed to maintaining this status.

Net-zero targets vary in their scope, with some applying to all GHGs and sectors of the economy and others applying to a subset of sectors and gases. A total of 73 net-zero targets cover all sectors, while the remainder do not specify sectoral coverage. A total of 51 cover all gases, 11 cover fewer than all gases, and the remainder do not specify. The vast majority of countries with net-zero targets fail to specify whether their targets cover international shipping and aviation, and whether they permit the use of international offsets. Six parties set separate targets for gross emission reductions and carbon removal, explicitly acknowledging the projected role that both reductions and removals will play in delivering their net-zero target.

3.4.2 Implementation details on G20 members' net-zero pledges

Responsible for three quarters of current global emissions, G20 members will largely determine when global emissions reach net zero. Encouragingly, all G20 members except Mexico and the African Union have set net-zero targets. Overall, however, limited progress has been made on key indicators of confidence in net-zero implementation, including legal status, the existence and quality of implementation plans and the alignment of near-term emission trajectories with net-zero targets (Rogelj *et al.* 2023).

Figure 3.4 presents a meta-analysis of the key characteristics of G20 members' net-zero targets, based on three independent trackers (Climate Action Tracker 2024b; Climate Watch 2024b; Net Zero Tracker 2024). (The criterion for inclusion in this analysis is that a tracker must track the net-zero targets of a majority of G20 members.) Nine G20 members have legally binding net-zero targets – the same as in last year's assessment – while 12 have published an implementation plan. A majority of these implementation plans, however, still lack concrete details and milestones to guide implementation at a granular level, with plans from only three parties – the European Union, France and the United Kingdom – rated as providing the highest-level information on anticipated pathways or measures for achieving the net-zero target across the two tracking databases assessed (Climate Action Tracker 2024b; Net Zero Tracker 2024). As peaking emissions is a prerequisite for achieving net zero, planning to peak emissions as soon and at as low a level as feasible, while laying the foundation for decarbonization thereafter, is a relevant near-term planning focus for countries where emissions have not yet peaked (see more discussion in section 3.4.3).

5 These figures do not count parties where net-zero pledges are under discussion and do not yet take one of the forms listed above.

Figure 3.4 **G20 net-zero target status and details**

	Source	Target year	Covers all sectors and gases	Transparent information on carbon removal	Published plan	Review process	Annual reporting
G20 members whose emissions have peaked							
Argentina	in policy document	2050	Fulfilled	Not fulfilled	Not fulfilled	No information	Not fulfilled
Australia	in law	2050	Fulfilled	Partially fulfilled	[inconclusive]	Partially fulfilled	Fulfilled
Brazil	in policy document	2050	No information	Not fulfilled	Not fulfilled	No information	Not fulfilled
Canada	in law	2050	Fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled	Fulfilled
European Union	in law	2050	Fulfilled	Fulfilled	Fulfilled	Fulfilled	Fulfilled
France	in law	2050	Fulfilled	Partially fulfilled	Fulfilled	Fulfilled	Fulfilled
Germany	in law	2045	Fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled	Fulfilled
Italy	in policy document	2050	Fulfilled	Partially fulfilled	Partially fulfilled	[not evaluated]	Fulfilled
Japan	in law	2050	Fulfilled	Not fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled
Russian Federation	in law	2060	Fulfilled	Partially fulfilled	Partially fulfilled	Partially fulfilled	Not fulfilled
South Africa	in policy document	2050	Partially fulfilled	Not fulfilled	Not fulfilled	No information	Not fulfilled
United Kingdom	in law	2050	Fulfilled	Fulfilled	Fulfilled	Fulfilled	Fulfilled
United States of America	in policy document	2050	Fulfilled	Fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled
G20 members whose emissions have not yet peaked							
African Union	no net-zero target						
China	in policy document	2060	No information	Not fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled
India	in policy document	2070	Partially fulfilled	Not fulfilled	Not fulfilled	No information	Not fulfilled
Indonesia	in policy document	2060	Partially fulfilled	Not fulfilled	[inconclusive]	No information	Not fulfilled
Mexico	no net-zero target						
Republic of Korea	in law	2050	Partially fulfilled	Fulfilled	Partially fulfilled	Partially fulfilled	Fulfilled
Saudi Arabia	government announcement	2060	No information	Not fulfilled	Not fulfilled	No information	Not fulfilled
Türkiye	in policy document	2053	Partially fulfilled	Not fulfilled	Partially fulfilled	No information	Not fulfilled

Fulfilled Partially fulfilled Not fulfilled No information

Note: More information about the indicators and criteria by which each G20 net-zero target is assessed, is provided in appendix B.

3.4.3 Implications of G20 NDCs and long-term pledges for peaking and net zero

In scenarios that limit warming to 1.5°C (>50 per cent), global emissions reach their peak before 2025, net-zero CO_2 by the early 2050s and net-zero GHGs by later in the century (Shukla *et al.* eds. 2022). The principle of common but differentiated responsibilities and respective capabilities in the light of different national circumstances, as well as different historical responsibility for warming seen to date, suggests that countries will not move in unison towards these benchmarks. Both the Paris Agreement and its first global stocktake outcome explicitly anticipate variation in peaking, noting respectively that peaking "will take longer for developing countries" and "may be shaped by sustainable development, poverty eradication needs and equity and be in line with different national circumstances." Within this context, G20 members' emissions trajectories are particularly important, accounting for the vast majority of global emissions.

Therefore, this section examines G20 members' emissions trajectories towards peaking and net zero as implied by their current emissions, their NDCs and their net-zero targets.[6] The section does not assess whether these targets or pathways towards their achievement are consistent with the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

G20 members are categorized as having peaked emissions if their year of maximum emissions occurred at least five years before the most recent year for which inventory data is available, noting that this definition does not consider emission trends following the peak year.[7] According to this definition, net emissions have peaked in ten of the G20 members. Figure 3.5 presents the rate of emissions change in these members through 2030, as implied by the NDCs, as well as the rate of emissions change after 2030, as implied by corresponding net-zero targets.

For most of these countries, current NDC targets suggest that progression to net zero will be backloaded. That is, their rate of decarbonization would need to accelerate after 2030 in order to reach net zero by the target year, most by 20 per cent or more. When emission reductions are backloaded, greater cumulative emissions occur prior to the net-zero year, contributing to greater warming than when reductions are not backloaded. Only three countries (Canada, the United Kingdom and the United States of America) would not need to accelerate decarbonization post-2030 in order to achieve their net-zero targets. Critically, however, none of these three countries is likely to achieve its NDC under current policies – so all of them will need to accelerate decarbonization in the near term. The Russian Federation, where emissions are currently increasing despite having peaked in 1990, will need to reverse course entirely in order to achieve its net-zero target. For G20 members where emissions have peaked, the period between peak and net-zero emissions is a minimum of 37 years (Japan) and extends to 60 years or more for the European Union and Russian Federation.

For the seven G20 members whose net emissions had not yet peaked as of five years before the most recent year for which inventory data is available, this section documents the implied or explicit commitments to peaking (figure 3.5). Of these G20 members, three (Indonesia, Mexico and the Republic of Korea) either explicitly or implicitly commit to peaking GHG emissions by 2030, while China commits to peaking CO_2 emissions before 2030. One (Türkiye) commits to peaking between 2030 and 2040 (in 2038). The remaining G20 members (India and Saudi Arabia) would not peak by 2030 according to their NDCs and do not specify post-2030 emissions trajectories other than their net-zero commitments. To achieve their net-zero goals, the countries in this group would need to transition from peak to net-zero emissions in much less time than the countries that have already peaked – in 15 to 40 years, versus 37 to more than 60 years.

This analysis highlights the limitations in G20 members' current approaches to achieving their net-zero targets, as implied by their NDCs. In countries where emissions have already peaked, most NDC targets suggest that emission reductions will be backloaded to later years, resulting in higher cumulative emissions in the near term combined with exacting rates of decarbonization in later decades. Greater near-term ambition in these countries could reduce cumulative emissions while avoiding reliance on potentially unrealistically rapid decarbonization later. Those countries whose emission reductions are not backloaded are not yet on track to achieve their NDCs, warranting greater near-term implementation efforts. On the other hand, in countries where emissions have not yet peaked, the anticipated period between peaking and net zero is quite short. Adhering to this time frame will be facilitated by striving in the near term for earlier and lower peaking, while laying the groundwork for rapid decline thereafter.

6 This analysis excludes the African Union because it does not have a collective NDC or net-zero target, as well as France, Germany and Italy, because they share an NDC with the European Union.

7 For the purposes of this assessment, countries are not considered to have peaked unless their year of maximum emissions occurs at least five years before the year for which the most recent inventory data is available (2019–2023, depending on the country). It is possible that some countries in figure 3.5 have already passed their maximum emission levels but are not yet categorized as having peaked because five years of subsequent inventory data are not yet available. For example, the Republic of Korea's emissions declined from 2018 to 2021 (the latest data available). If this trend were to continue as data for 2022 and 2023 became available, then the Republic of Korea would be classified as having peaked emissions in 2018.

Figure 3.5 Implied emissions trajectories of G20 members

G20 members whose emissions have peaked

Member	Peak year	Net-zero target year	Years from peak to net-zero	Likely to achieve NDC under current policies?	Average annual rate of change 2019–2030 to achieve NDC (% relative to 2019)	Average annual rate of change 2030–net-zero year to achieve net-zero target (% relative to 2019)
Argentina	2007	2050	43	Less likely	-0.1%	↗ -5.0%
Australia	2007	2050	43	Less likely	-2.6%	↗ -3.6%
Brazil	2004	2050	46	Less likely	-1.9%	↗ -4.0%
Canada	1999	2050	51	Less likely	-3.8%	↘ -2.9%
European Union	≤1990	2050	≥60	More likely	-3.1%	↗ -3.3%
Japan	2013	2050	37	Less likely	-2.9%	↗ -3.4%
Russian Federation	1990	2060	70	More likely	3.7%	↗ -4.7%
South Africa	2009	2050	N/A	Less likely	-1.8%	N/A
United Kingdom	1991	2050	59	Less likely	-3.5%	↘ -3.1%
United States of America	2007	2050	43	Less likely	-3.7%	↘ -3.0%

Decarbonization rate post 2030, assuming NDC is achieved:
need to accelerate ↗
no need to accelerate ↘

G20 members whose emissions have not yet peaked

Member	Stated or implied peak year or period	Net-zero target year	Maximum possible years from peak to net-zero	Likely to achieve NDC under current policies?
China	<2030	<2060	38	More likely
India	>2030	2070	<40	More likely
Indonesia	2030	2060	30	Less likely
Mexico	2026	N/A	N/A	More likely
Saudi Arabia	>2030	2060	<30	Less likely
Republic of Korea	≤2030	2050	32	Less likely
Türkiye	2038	2053	15	More likely

Note: Emissions figures are for GHG emissions including LULUCF. South Africa's net-zero goal covers only CO_2, while its NDC covers all GHGs, so it is not possible to calculate a rate of change for GHGs post-2030 or years from peak to net zero GHGs. South Africa's rate of change from 2019-2030 is calculated on the basis of its conditional NDC. Countries are designated as needing to "marginally" accelerate decarbonization post-2030 if the needed acceleration is less than 10 per cent.

4 The emissions gap in 2030 and 2035

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4.1 Introduction

This chapter updates the assessment of the emissions gap, which refers to the difference between the estimated global greenhouse gas (GHG) emissions resulting from the full implementation of the latest nationally determined contributions (NDCs) and the emissions under the least-cost pathways that limit warming to specific levels, from 1.5°C up to 2°C. The chapter also examines whether NDC targets will be achieved by existing policies, or whether there is an implementation gap between the pledged GHG emission reductions and those projected under current policies. Neither pledges nor policies changed markedly compared with last year. Least-cost pathways in line with limiting warming to specific temperature levels also remain the same, although this year's report highlights the implications of the time lost since 2020 for achieving deep emission reductions by 2030.

Chapter 4 focuses on what is required now and what will be required in the next NDCs (which will include mitigation targets for 2035) to maintain the possibility of achieving the long-term temperature goal of the Paris Agreement. In this context, the key questions answered by this chapter are:

- What are the global milestones in 2030, 2035 and 2050 for limiting global warming to well below 2°C and preferably 1.5°C?
- What emission levels do current pledges and policies result in by 2030 and 2035, and how do they compare with the global milestones?
- What are the implications for the level of global ambition and implementation action required to bridge the emissions gaps in 2030 and 2035?
- What are the implications for global warming over the course of this century?

4.2 Scenarios for assessing the 2030 and 2035 emissions gap

The emissions gap assessment draws on a set of scenarios divided into four categories: a current policies reference scenario, NDC scenarios, the strongest pledge scenario, and least-cost mitigation scenarios aligned with specific temperature limits (table 4.1). These scenarios provide the background for estimating the emissions gap and the global temperature outcomes discussed in sections 4.3 and 4.4, respectively.

Table 4.1 Summary of scenarios selected for the emissions gap assessment and global warming projections

Category	Scenario cases	Cut-off year	Scenario description
Reference scenario	Current policies	2023	This scenario projects global GHG emissions assuming all currently adopted and implemented policies as at November 2023 are realized and that no additional measures are undertaken. When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.
NDC scenarios	Unconditional NDCs	2024	This scenario projects the GHG emissions assuming full implementation of the most recent NDCs that do not depend on explicit external support (cut-off date: September 2024). When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.
	Conditional NDCs	2024	In addition to the unconditional NDCs, this scenario encompasses the most recent NDC targets for which implementation is contingent on receiving international support, such as finance, technology transfer and/or capacity-building (cut-off date: September 2024). When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.
Strongest pledge scenario	Conditional NDCs + all net-zero pledges	2023	This is the most optimistic scenario included. It assumes the achievement of the conditional NDC scenario until 2030 and all net-zero or other long-term low emissions development strategy (LT-LEDS) pledges (cut-off date: July 2024) thereafter.
Mitigation scenarios consistent with limiting global warming to specific levels	Below 2°C	N/A	A least-cost pathway starting from 2020 and consistent with keeping global warming below 2°C throughout the twenty-first century with at least a 66 per cent chance.
	Below 1.8°C	N/A	Least-cost pathway starting from 2020 and consistent with holding global warming below 1.8°C throughout the twenty-first century with at least a 66 per cent chance.
	Around 1.5°C (with no or limited overshoot)	N/A	Least-cost pathway starting from 2020 and ensuring that global warming is kept below 1.5°C with at least a 33 per cent chance throughout the entire century and is brought back below 1.5°C with at least a 50 per cent chance by 2100. This pathway reaches net-zero GHG emissions in the second half of the century.

All the scenarios follow methodologies similar to previous editions of the Emissions Gap Report. Further details are provided in appendix D of this year's report and in appendix C of last year's (United Nations Environment Programme [UNEP] 2023). Scenario estimates are summarized in table 4.3.

While the assessment of the current policies scenario is based on the modelling studies covered by the Intergovernmental Panel on Climate Change Working Group III *Sixth Assessment Report* (IPCC WGIII AR6) (Lecocq *et al.* 2022), it uses more recent GHG emissions projections by these studies: Climate Action Tracker (2023); PBL Netherlands Environmental Assessment Agency (den Elzen *et al.* 2023; den Elzen *et al.* 2024; Nascimento *et al.* 2023), Joint Research Centre–Global Energy and Climate Outlook (Keramidas *et al.* 2023) and ENGAGE (Riahi *et al.* 2021; Tagomori *et al.* 2023). In addition, the GHG emissions projections of the International Energy Agency (IEA) STEPS scenario, set forth in the IEA World Energy Outlook 2023, are included (IEA 2023; IEA 2024a). The consideration of these sources leads to global 2030 GHG emissions projections under current policies of 57 gigatons of carbon dioxide equivalent ($GtCO_2e$) (range: 53–59), which is slightly higher (about 1 $GtCO_2e$) than last year's assessment (table 4.3).

The updated NDC scenarios reflect the latest updates available, based on findings from four modelling exercises conducted by Climate Action Tracker (2023), the Joint Research Centre–Global Energy and Climate Outlook (Keramidas *et al.* 2023), PBL Netherlands Environmental Assessment Agency (den Elzen *et al.* 2022; den Elzen *et al.* 2023) and Meinshausen *et al.* (2023).

Scenario extensions are used to explore the post-2030 implications of current policies, NDCs and net-zero pledges including LT-LEDS.[1] Because GHG projections further into the century are subject to much larger policy

1 For a technical discussion and details of the method, see UNEP (2023).

uncertainty than projections to 2030, two cases are presented to reflect the full range of potential futures based on the mitigation pledges currently put forward by countries (Rogelj *et al.* 2023). The most conservative case simply assumes a continuation of the current policies scenario. At the other end of the range, the most stringent pledge-based scenario, called strongest pledge scenario, assumes the full implementation of the conditional NDCs until 2030 and the full achievement of all pledged net-zero-emissions targets, including LT-LEDS.

Box 4.1 Have global GHG emissions peaked or are they about to?

Although global GHG emissions reached a record high in 2023 and are now above pre-pandemic levels, they are gradually plateauing (chapter 2; Dhakal *et al.* 2022; Forster *et al.* 2024). This raises the question: Did global emissions peak in 2023 or will they peak soon?

The peaking of emissions depends on several uncertain factors. First, clean technology uptake in low- and middle-income regions (particularly China and India) must outpace energy demand growth and avoid any additions of fossil sources. Second, countries and regions that have peaked emissions (predominantly Europe) must sustain emission reductions beyond the decarbonization of the power sector, which has seen most progress to date. Third, natural and indirect anthropogenic influences, such as climate-related drops in hydropower generation and effects of warming on land-use emissions and fires can affect peaking (see box 2.1). Together this makes it difficult to assess if and when global emissions peak.

Still, there are signs of progress. Recent analysis finds that if current clean technology growth trends continue and some progress is made to cut non-CO_2 emissions, there is a 70 per cent chance that emissions will decline in 2024 (Fyson *et al.* 2023). If this materializes, 2023 could mark the peak of global GHG emissions, though this can only be verified after several years of steady emissions decline.

Early trends in 2024 give mixed signals. On the positive side, renewable energy capacity grew by around 500 GW in 2023, with China, the European Union and United States of America accounting for 83 per cent of additions (IEA 2024b; International Renewable Energy Agency 2024). Renewables may grow faster in 2024 than in 2023 (Wiatros-Motyka, Fulghum and Jones 2024), driven by record additions of wind and solar in China, combined with a rebound in hydropower generation (Myllyvirta 2024a). China's fossil CO_2 emissions fell by 1 per cent in the second quarter of 2024, and the share of coal in power generation dropped to a record low of 53 per cent in May 2024 (Myllyvirta 2024a; Myllyvirta 2024b). If these trends hold, fossil CO_2 emissions from China, the world's largest emitter, may have peaked in 2023.

However, the latest data suggest that global power sector emissions are less likely to fall in 2024 than previously expected, because of a surge in electricity demand driven by economic growth, intense heatwaves in the first part of 2024 and the electrification of road transport (IEA 2024c; Wiatros-Motkya, Fulghum and Jones 2024). Current forecasts indicate that electricity demand growth in 2024 (+1200 TWh/year) will exceed the assumptions made by Fyson *et al.* (2023) and potentially delay the peak in fossil fuel use and emissions. IEA estimates that the increase in electricity demand will delay the peak in coal demand to 2024 (IEA 2024d). Outlooks for oil and gas demand also point to continued growth in 2024, and methane emissions continue to accelerate (IEA 2024e; IEA 2024f; Shindell *et al.* 2024).

The scenarios of this chapter confirm the assessment of near-term trends and the importance of accelerating implementation to achieve global peaking in the next few years. The current policies scenario projects that global GHG emissions roughly stabilize between 2025 and 2030, while the unconditional and conditional NDC scenarios project a declining path before 2030 (figure 4.1).

The world may be on the cusp of peaking global CO_2 and GHG emissions, thereby achieving a critical milestone on the much longer path towards net-zero emissions. Peaking before 2025 remains possible but hinges on the acceleration of the energy transition and curbing of fossil fuel supply and demand.

Three least-cost scenarios consistent with limiting global warming to specific levels are included with levels of warming relevant in the context of the Paris Agreement: 2°C, 1.8°C and 1.5°C. The underlying GHG emissions trajectories for each temperature level are drawn from the IPCC WGIII AR6 database (Byers *et al.* 2022; Riahi *et al.* 2022), while corresponding temperature projections are based on the IPCC WGI AR6 physical science assessment (Nicholls *et al.* 2021; Kikstra *et al.* 2022) and consistent with the recent updates to the remaining carbon budget Forster *et al.* (2024) (table 4.2).

Below 2°C and 1.8°C scenarios limit global warming to these levels with at least a 66 per cent chance throughout the century. 1.5°C scenarios have a lower chance of keeping warming below 1.5°C throughout the century, which is why they are qualified as having "no or limited overshoot". The "no or limited overshoot" characteristic is captured by ensuring that the chance of warming being limited to 1.5°C throughout the entire twenty-first century is never less than 33 per cent, identical to the C1a category definition used by the IPCC WGIII AR6 report. Aligned with the definitions used in the IPCC Special Report on global warming of 1.5°C and AR6, the chance of returning warming to 1.5°C is set to at least 50 per cent. Because of the limit to peak warming, a strengthening of this to at least 66 per cent in line with the other scenarios would have limited effect on the emissions milestones in 2030, 2035 and through to mid-century. But it would affect emissions and removal levels in the second half of the century, when a higher chance of returning warming to 1.5°C would imply a larger deployment of net-negative emissions by means of CO_2 removal.

The least-cost scenarios are based on stringent mitigation action starting in 2020, whereas the current policies and NDC scenarios are based on recent updates, revealing a discrepancy between the scenarios (see box 4.2 on time lost). Updated least-cost scenarios that start the emission reduction pathways in more recent years are only just beginning to appear in the literature. Once this literature develops further, the least-cost mitigation pathways of this report can be updated.

Table 4.2 Global total GHG emissions in 2030 and 2050 and global warming characteristics of different scenarios consistent with limiting global warming to specific temperature limits

Scenario	Number of scenarios	Global total GHG emissions ($GtCO_2e$)			Estimated temperature outcome			
		In 2030	In 2035	In 2050	50% chance	66% chance	90% chance	Nearest IPCC WGIII AR6 scenario class
Below 2°C (>66% chance)*	195	41 (37–46)	36 (31–39)	20 (16–24)	Peak: 1.7–1.8°C In 2100: 1.4–1.7°C	Peak: 1.8–1.9°C In 2100: 1.6–1.9°C	Peak: 2.2–2.4°C In 2100: 2–2.4°C	C3a
Below 1.8°C (>66% chance)*	139	35 (28–41)	27 (21–31)	12 (8–16)	Peak: 1.5–1.7°C In 2100: 1.3–1.6°C	Peak: 1.6–1.8°C In 2100: 1.4–1.7°C	Peak: 1.9°C–2.2°C In 2100: 1.8–2.2°C	N/A
Around 1.5°C (>50% chance in 2100 with no or limited overshoot)*	50	33 (26–34)	25 (20–27)	8 (5–13)	Peak: 1.5–1.6°C In 2100: 1.1–1-3°C	Peak: 1.6–1.7°C In 2100: 1.2–1.5°C	Peak: 1.9–2.1°C In 2100: 1.6–1.9°C	C1a

* Values represent the median and twentieth–eightieth percentile range across scenarios. Probabilities refer to peak warming at any time during the twenty-first for the below 1.8°C and below 2°C scenarios. When achieving net-negative CO_2 emissions in the second half of the century, global warming can be further reduced from these peak warming characteristics, as shown in the "Estimated temperature outcome" columns. For the around-1.5°C scenarios, the probability applies to the global warming in the year 2100, while the "no or limited overshoot" characteristic is captured by ensuring that projections do not exceed 1.5°C with more than 67 per cent probability over the course of the twenty-first century or, in other words, that the lowest probability of warming being limited to 1.5°C throughout the entire twenty-first century is never less than 33 per cent. This definition is identical to the C1a category definition used by the IPCC WGIII AR6 report. The UNEP Emissions Gap Report analysis uses scenarios that assume immediate action from 2020 onwards.

Note: GHG emissions in this table have been aggregated with the 100-year global warming potential values from AR6.

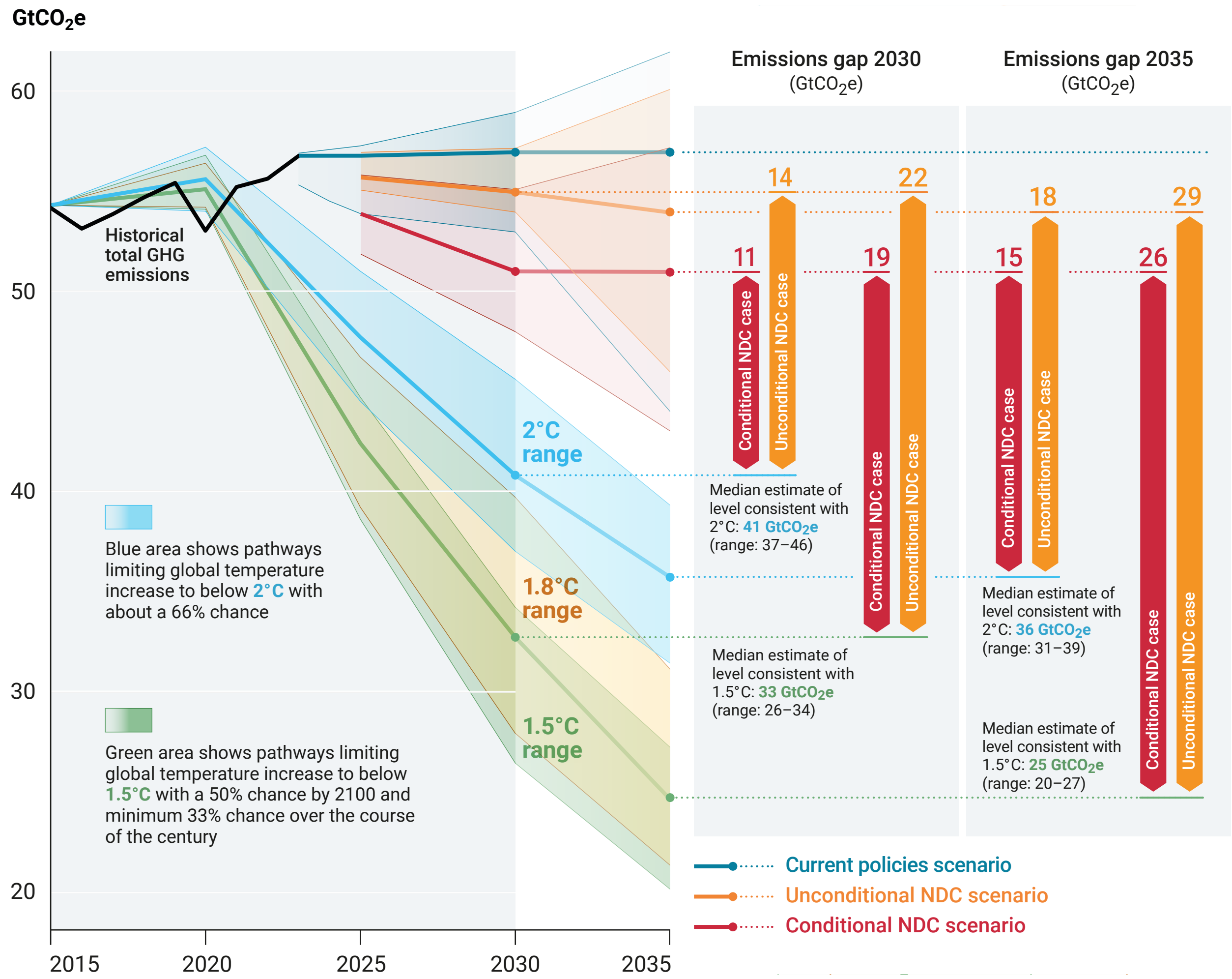
4.3 The emissions gaps in 2030, 2035 and 2050 remain large

The emissions gap shows how far countries' mitigation pledges are from the levels scientific evidence tells us are necessary. It is defined as the difference between the estimated global GHG emissions resulting from the full implementation of the latest NDCs and those under least-cost pathways aligned with the Paris Agreement's long-term temperature goal of limiting global warming to well below 2°C while pursuing efforts to limit it to 1.5°C above pre-industrial levels. The following sections estimate the emissions gap in 2030 (section 4.3.1), 2035 (section 4.3.2) and 2050 (section 4.3.3). The assessment sends a strong message to countries as they prepare their next NDCs. Meeting the long-term temperature goal of the Paris Agreement will only be possible if three things happen: action today to close the 2030 and 2035 emissions and implementation gap; action to submit new NDCs with ambitious mitigation targets for 2035; and sustained action to expand and deliver committed emission reductions thereafter.

4.3.1 Bridging the 2030 emissions gap requires accelerated implementation

The emissions gap in 2030 remains unchanged compared with last year's assessment (figure 4.1 and table 4.3), since there have been no submissions of new NDCs that affect global emissions, no updates to the quantification of their implications and no updates to the least-cost pathways. Full implementation of unconditional NDCs is estimated to result in a gap with below 2°C pathways of about 14 $GtCO_2e$ annually (range: 13–16 $GtCO_2e$), and 22 $GtCO_2e$ (range: 21–24 $GtCO_2e$) with 1.5°C pathways. If, in addition, conditional NDCs are fully implemented, these gaps are reduced by approximately 3 $GtCO_2e$.

Figure 4.1 GHG emissions under different scenarios and the emissions gap in 2030 and 2035



Note: For the current policies and NDC scenarios, median estimates and min–max ranges are shown. The scenarios consistent with limiting global warming to 2°C, 1.8°C and 1.5°C show medians and twentieth–eightieth percentile range.

Full implementation of unconditional and conditional NDC scenarios reduces emissions in 2030 relative to 2019 levels by 4 and 10 per cent respectively, whereas a 28 per cent reduction is needed for 2030 emissions to be aligned with 2°C and a 42 per cent reduction is needed for 1.5°C.[2] These estimates are the same as those in the 2023 assessment, but with one year less until 2030, their achievement becomes more challenging (see box 4.2).

Table 4.3 Global total GHG emissions in 2030, 2035 and 2050 and estimation of associated emissions gaps under different scenarios

Scenario	Projected GHG emissions ($GtCO_2e$)	Estimated emissions gaps ($GtCO_2e$)		
	Median and range	Below 2°C	Below 1.8°C	Around 1.5°C
2030				
Current policies	57 (53–59)	16 (12–18)	22 (18–24)	24 (20–26)
Unconditional NDCs	55 (54–57)	14 (13–16)	20 (19–22)	22 (21–24)
Conditional NDCs	51 (48–55)	11 (7–14)	17 (13–20)	19 (15–22)
2035				
Current policies continued	57 (44–62)	21 (9–26)	30 (18–35)	32 (20–37)
Unconditional NDCs continued	54 (46–60)	18 (10–24)	27 (19–33)	29 (21–35)
Conditional NDCs continued	51 (43–57)	15 (8–22)	24 (17–30)	26 (19–33)
Conditional NDC + all net-zero pledges	43 (38–49)	8 (2–13)	16 (11–22)	19 (13–24)
2050				
Current policies continued	56 [25–68]	36 (4–48)	44 (12–56)	48 (16–60)
Conditional NDC + all net-zero pledges	19 [6–30]	-1 (-14–10)	7 (-6–18)	11 (-2–22)

Note: Scenarios are defined in table 4.1. The 2030 median current policies estimate is about 0.5 $GtCO_2e$ higher (rounding results in 1 $GtCO_2e$ higher in the table) than the median estimate of last year's assessment, mainly due to the impact of updated recent emissions trends and methodological updates.

The GHG emissions ranges for 2035 and 2050 show the minimum–maximum range across different projection-model assumptions and include 2030 current policy/NDC assessment uncertainty (UNEP 2023, chapter 4, appendix C). That means that the uncertainty over which emissions current policies or NDCs will result in for 2030 and the ambiguity in how this can be extended into the future are captured by this range. The gap numbers and ranges are calculated based on the original numbers (without rounding), and these may differ from the rounded numbers in the table. Numbers are rounded to full $GtCO_2e$. The gap numbers and ranges are calculated as the difference between the median and minimum and maximum estimates for GHG emissions of the current polies and NDC scenarios and the median estimate for GHG emissions of the least-costs scenarios in line with specific temperature limits. GHG emissions have been aggregated with the 100-year global warming potential values from AR6.

Adding to the challenge, there are no signs of accelerated implementation, and countries are not even on track to deliver on their current NDCs (see also chapter 3). In other words, there is an implementation gap between the projected emissions based on policies currently in place and those under full NDC implementation (den Elzen *et al.* 2019; Roelfsema *et al.* 2020; Fransen *et al.* 2023).[3] This gap is about the same as in last year's assessment: about 2 $GtCO_2e$ (range: 0–3 $GtCO_2e$) for unconditional NDCs and 5 $GtCO_2e$ (range: 2–9 $GtCO_2e$) for conditional NDCs in 2030.

Altogether, this implies that rapid and deep annual emission reductions of about 5.5 per cent and 9.0 per cent are needed from now until 2030 to bridge the emissions gap for below 2°C and 1.5°C pathways respectively. Chapter 6 shows that there are plenty of opportunities to do so.

2 These percentages are slightly different than those provided in the IPCC WGIII AR6 report, which may reflect that the the Emissions Gap Report percentages are based on updates to 2019 emission levels compared with the AR6.

3 Note that the implementation gap in this report refers to the gap between policy adoption and pledges, but an additional implementation gap may exist between intended and ultimate outcomes of adopted policies (Fransen *et al.* 2023).

4.3.2 The 2035 emissions gap implied by current scenarios can be closed with accelerated implementation today, ambitious new NDCs and sustained action thereafter

Countries are expected to include mitigation targets for 2035 in the next NDCs due in February 2025. While the emissions gap for 2035 based on the next NDCs can only be calculated next year, this section explores the outlook for the 2035 emissions gap based on extensions of the current policies and NDC scenarios (table 4.3).

As table 4.3 shows, a continuation of the current NDC scenarios would result in an increase in the emissions gap in 2035 of 4 $GtCO_2e$ for a 2°C warming limit, and 7 $GtCO_2e$ for a 1.5°C limit, whereas a continuation of the mitigation effort implied by current policies would lead to an even wider gap in 2035.

Box 4.2 What are the implications of time lost since 2020?

The mitigation scenarios consistent with limiting global warming to 1.5°C, 1.8°C and 2°C assume that least-cost climate strategies start from 2020 and result in strong reductions in GHG emissions already during 2020–2030 (table 4.3). However, following the COVID-19-induced dip in emissions in 2020, global GHG emissions, including methane, have continued to increase (see chapter 2; Forster *et al.* 2024). This time lost has several implications, the severity of which depends on what happens next.

The CO_2 emissions that have been added to the atmosphere since 2020 have further reduced the remaining carbon budget for limiting warming to below 2°C (>66 per cent chance) and around 1.5°C (>50 per cent chance) to 900 and 200 $GtCO_2$, respectively (Forster *et al.* 2024).

Assuming that the emissions gap is still bridged by 2030, between 20 and 35 Gt of additional cumulative CO_2 emissions will be emitted over the period 2020–2030, compared with the mitigation scenarios consistent with limiting global warming to specific targets. This would result in warming of about 0.01 to 0.02°C higher than original pathways indicate. A lack of deep methane reductions would also contribute to higher warming (Rogelj and Lamboll 2024; Shindell *et al.* 2024). As chapter 6 shows, theoretically the technical emissions reduction potential for 2030 and 2035 is still sufficient to bridge the emissions gap.

However, a more severe consequence of the time lost since 2020 is that the deepest emission reductions by 2030 become harder to achieve because of the continued lock-in of carbon-intensive infrastructure and less time left to realize the emission reductions required. This reduces the feasibility of bridging the gap by 2030. A recent study on institutional, geophysical and technological feasibility issues explored the impact of recent emission trends, revealing a low overshoot of 0.1°C median warming above 1.5°C for the deepest emission scenarios. This underscores how delays until 2023 have already raised the minimum level of global warming that must be anticipated (Bertram *et al.* 2024). Each year of delay also compounds climate impacts, some of which are irreversible (Nauels *et al.* 2019).

Global ambition in the next NDCs must reduce global GHG projections for 2035 by 37 and 57 per cent below 2019 levels to achieve levels consistent with below 2°C and 1.5°C pathways, respectively. Strong action before 2030 is needed for this to remain feasible. Unless global emissions in 2030 are brought below levels resulting from current policies and from the full implementation of the current NDCs, it will become impossible to limit warming to 1.5°C with no or limited overshoot, and strongly increase the challenge of limiting warming to 2°C (Pathak *et al.* 2022).

To illustrate, the data underlying the gap assessment indicate that, if stringent climate action starts in 2024, the annual emission reductions required to meet the emission levels in 2035 consistent with below 2°C and 1.5°C scenarios are 4 and 7.5 per cent per year on average, which is about 1.5 percentage points lower than the reduction rates to meet the emission levels in 2030 (section 4.3.1). However, if countries only achieve the current unconditional NDC emission levels in 2030 and postpone stringent mitigation until then, the required cuts in emissions double to about 8 per cent per year from 2030 to 2035 for the below 2°C scenario and 15 per cent per year on average for the 1.5°C scenario.

Countries should not only fully implement but also go beyond their current NDC targets for 2030 to maintain the possibility of limiting global warming to 1.5°C with no or limited overshoot. An acceleration of near-term implementation will also enable countries to put forward more ambitious mitigation targets for 2035 in their next NDCs. It will also make achieving those targets more feasible.

4.3.3 The emissions gap in 2050 depends on action now and a transition to net-zero emissions

By mid-century, the results indicate an even larger emissions gap than those found for 2030 and 2035. In the most conservative case of current policies continued, the emissions gap grows to 36–48 $GtCO_2e$ in 2050, relative to least-cost pathways that limit warming to 2°C and 1.5°C, respectively.

Both numbers are accompanied by large uncertainty ranges resulting from the ambiguity in how near-term policies are projected several decades into the future.

The most optimistic case of this report, where all conditional NDCs and long-term net-zero targets are achieved, provides an alternative extreme. In this case, both the gap and surrounding uncertainties shrink to -1, 7 and 11 $GtCO_2e$ compared with least-cost pathways limiting warming to 2°C, 1.8°C and 1.5°C, respectively (see table 4.3). However, this most optimistic case should be interpreted cautiously because most countries do not have NDCs, implementation plans or finance that are aligned with achieving their long-term net-zero targets (see chapters 3 and 6). This highlights both the challenge of steering economies from past trends towards sustainable, low-carbon futures and the opportunity and the necessity of improved, strengthened and ambitious new NDCs for 2035 as they are the near-term steps that will determine the likelihood and credibility of long-term pledges being implemented and achieved.

4.4 Immediate action matters for temperature implications

As in previous years, the temperature implications of the emissions gap are estimated by projecting emissions over the twenty-first century and assessing their global warming implications with a reduced-complexity climate model FaIR that is calibrated to the AR6 assessment (Kikstra *et al.* 2022; Nicholls *et al.* 2021; Smith 2023). Projections until the end of the century are inherently uncertain and subject to scenario assumptions, such as the level at which climate action continues or how technology costs develop. These uncertainties are reflected in large ranges (reported in figure 4.2) surrounding the central warming projections indicated below. The Emissions Gap Report's temperature projections are consistent with those from other major assessments, such as the IEA Announced Pledges Scenario, Climate Action Tracker and the 2023 United Nations Framework Convention on Climate Change NDC Synthesis Report (all of which report temperature projections with a 50 per cent chance).

A continuation of the mitigation effort implied by current policies limits global warming to a maximum of 3.1°C over the century with a 66 per cent chance, while there remains a 10 per cent likelihood that warming could exceed 3.6°C. Continuations of either unconditional or conditional NDCs lower these projections, but even the more ambitious of these projections does not keep warming below 2.5°C with at least a 66 per cent chance. By 2050, these scenarios see global warming well above 1.5°C and with up to a 1-in-3 likelihood (34 per cent) that warming already exceeds 2°C by then.

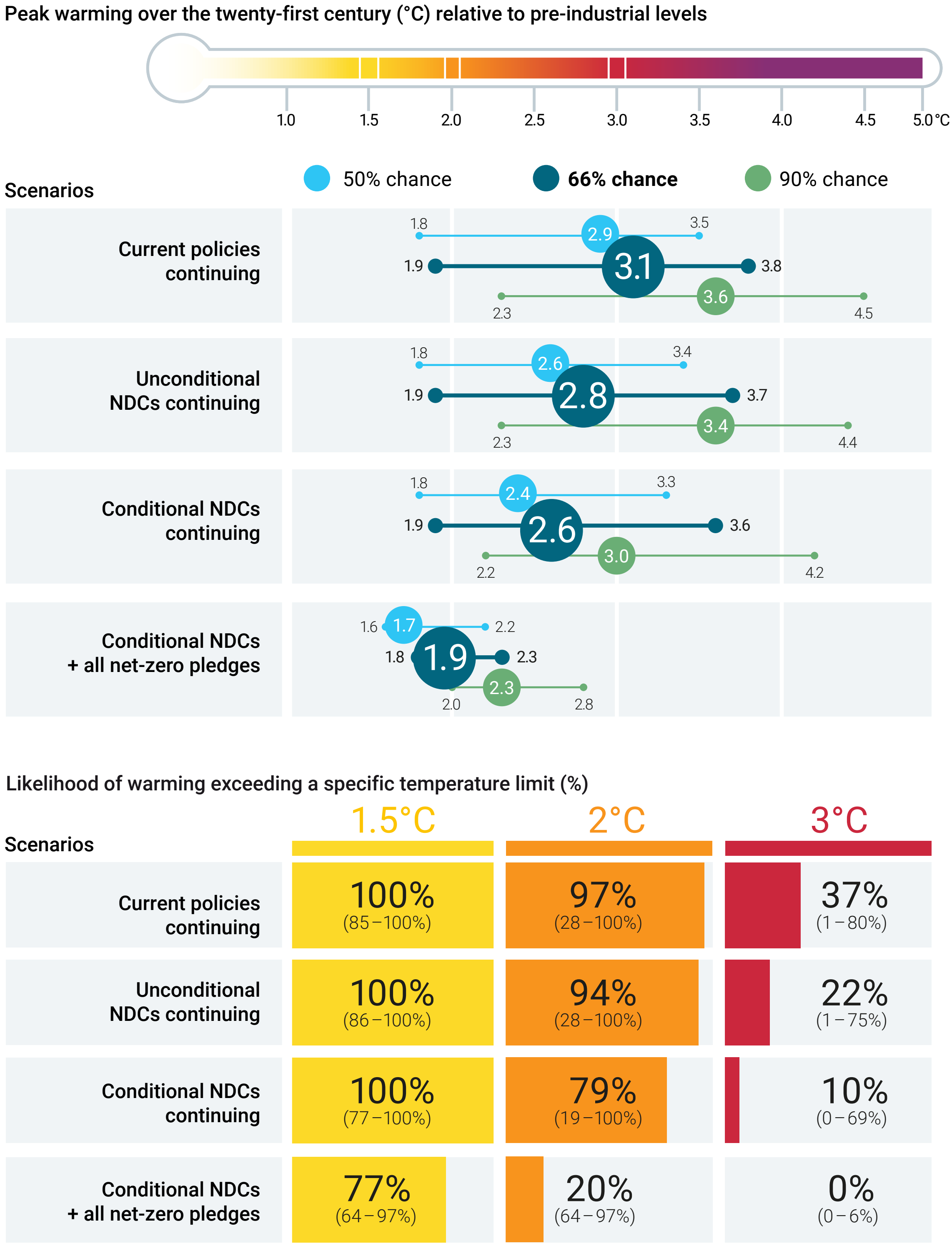
The most optimistic pledge-based scenario, which combines the full implementation of conditional NDCs and all net-zero pledges, would limit warming over the course of the century to 1.9°C with a 66 per cent chance, leaving a 10 per cent likelihood that it ends up above 2.2°C. Besides the difference in warming, an important distinction is that this is the only scenario under which the best-estimate global warming is halted over the course of this century. In the other scenarios, warming has not yet stabilized by 2100, and temperature would continue to rise into the twenty-second century. In all but the most optimistic scenario in figure 4.2, the likelihood of exceeding 1.5°C over the course of this century is virtually certain. The median warming estimate for the most optimistic scenario is 1.7°C, suggesting a 0.2°C of exceedance of 1.5°C.

The scenarios above highlight the crucial impact of immediate action on temperature projections, and a renewed focus on closing the implementation gap to avoid lock-in. Projections based on the implementation and continuation of the mitigation effort implied by conditional NDCs show approximately 0.5°C lower peak warming compared with those based on current policies. Further, fulfilling near-term conditional NDCs enhances the chance of achieving net-zero pledges and LT-LEDS, which further reduce global warming projections. Including all available LT-LEDS and net-zero targets decreases peak global warming projections by an additional 0.5°C. Even in the most optimistic scenarios based on current pledges, there remains about a 3-in-4 chance (77 per cent) that warming will exceed 1.5°C, with a significant chance that global warming could surpass 2°C (1-in-5) and a non-zero chance that it exceeds 2.5°C or higher levels of warming.

Box 4.3 Have we already missed 1.5°C?

If the mitigation ambition implied by current policies and NDCs continues, then there is virtually no chance of limiting warming to 1.5°C. The reasons for this are clear: current policies and current NDCs do not result in clear emission reductions in the near term and the rate of warming over the next decades is therefore not expected to change much from the current rate of about a 0.25°C per decade (Forster *et al.* 2024). Current levels of global warming are about 1.3°C (Forster *et al.* 2024), which means that 1.5°C above pre-industrial levels would be reached in less than a decade. The chance of warming ending up close to or below 1.5°C increases tremendously in response to two factors: an increase in the delivery of emission reductions over the next years, and the continuation thereof towards the achievement of net-zero targets by mid-century and beyond. The current most optimistic case sees median (50 per cent) warming projections capped at about 1.7°C (figure 4.2). Overachieving 2030 NDC targets i.e. bringing emission levels in 2030 below those implied by the current NDCs, and submission of ambitious new 2035 NDCs are therefore key to keeping warming as close to 1.5°C as possible.

Figure 4.2 **Projections of global warming under the pledge-based scenarios assessed in this chapter**



Note: The ranges reflect the scenario uncertainty taking into account the range of emissions estimates for 2030 and the variations in their extensions (UNEP [2023], section C.4.1). It illustrates the full minimum–maximum variation across assumptions for 2030 emissions and for extensions. The Emissions Gap Report typically presents the temperature projections and the avoidance of temperature limits at the 66 per cent chance level. Other levels (50 and 90 per cent) are included for completeness.

5 Bridging the gap: Translating global milestones into action and ambition in the next nationally determined contributions of G20 members

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5.1 Introduction

One of the reasons for the successful adoption of the Paris Agreement is that it builds on a bottom-up approach, whereby countries communicate their nationally determined contributions (NDCs) towards meeting the collective long-term goals of the agreement. The global emissions and temperature implications of the next NDCs can therefore only be estimated once all the individual NDCs are submitted and can be aggregated. Nonetheless, the outcome of the first global stocktake encourages countries to align their next NDCs with limiting global warming to 1.5°C (United Nations Framework Convention on Climate Change [UNFCCC] 2024, chapter 1). A central question as countries prepare their next NDCs is, therefore, how alignment with the Paris Agreement's temperature goal can be interpreted at the national level.

There is no simple or single answer to this question. However, it is possible to gain an understanding – based on top-down modelling approaches – of the ranges of mitigation ambition and action that would be needed from various countries or groups of countries in their next NDCs, to align with scenarios that are consistent with limiting global warming over this century to below 2°C and 1.5°C respectively, as described in chapter 4. For the purposes of this chapter, the focus is on the G20 members collectively (section 5.2). In line with previous chapters, the African Union is not assessed, as it does not have an organization-wide emission reduction target like the European Union.

At the same time, it is possible to gain an understanding of the ranges of ambition and action that would be feasible at country level, based on bottom-up national scenarios that achieve national development priorities alongside ambitious mitigation action (section 5.3). Such scenarios are emerging for many countries. While country-level modelling approaches generally do not ensure global alignment with below 2°C and 1.5°C scenarios, they can better represent specific context, capabilities and dynamics at the national level, and provide granular insights on implementation pathways to set and achieve ambitious targets (see also chapter 6).

Together, the bottom-up and top-down approaches can provide valuable information for countries on how to ensure that their next NDCs reflect the highest possible ambition, in accordance with article 4 of the Paris Agreement (2015).

5.2 Interpretations of Paris-aligned action and ambition of G20 members show that they must move faster than the global average

This section presents considerations and findings on how global emissions reduction milestones can be translated to milestones for countries or groups of countries. It provides results for the G20 collectively, although the methodologies could be used to explore results at the national level.

Two methods are considered. Both start from a global emission pathway which stays below a given temperature limit but allocate emissions to the national level using different principles. Together, they can be used to provide perspectives on what a fair and ambitious NDC at the national level could entail.

Distributing emissions to the national level based on cost-effectiveness highlights in which countries and sectors it is cheapest to cut emissions. This method is criticized, as it does not consider whether the distribution of future emissions reductions is aligned with any given equity principle. This is crucial, because, as "it is only in relation to such a 'fair share' that the adequacy of a state's contribution can be assessed in the context of a global collective action problem" (Patt *et al.* 2022).

Defining an equitable allocation of future mitigative effort based on different equity principles provides a way to distribute mitigation effort fairly. This is also not without its challenges, as equity is multifaceted and no such calculation is value-neutral; nor are those that combine fair-share principles or consider a spectrum of approaches. As this method considers transferable emissions allocations rather than physical emissions (Kartha *et al.* 2018), the ambition levels provided by this method could be met by a combination of domestic implementation and international support for emissions reductions elsewhere.

A wide range of equity approaches have been developed (Höhne, den Elzen and Escalante 2014; Pan, Teng and Wang 2014; Robiou du Pont *et al.* 2017; van den Berg *et al.* 2020; Winkler *et al.* 2011) based on philosophical (Caney 2021) and legal (Rajamani *et al.* 2021) interpretations of equity. These approaches consider (among others) the historical responsibility of nations, their capability and their needs. Not only the choice of equity principles affects the final fair-share allocation but also the parametrization and implementation of the approach (van den Berg *et al.* 2020). It is important that approaches are clear about their normative assumptions to transparently inform the political process (Dooley *et al.* 2021; Kartha *et al.* 2018).

In the absence of a consensus on fair-share principles and implementations, some approaches combine several equity principles into one fair-share allocation scheme (Kemp-Benedict *et al.* 2019; McKinnon *et al.* 2023), while others consider a representative allocation from a large spectrum of allocations (Climate Action Tracker 2023a; Robiou du Pont and Meinshausen 2018), although this is criticized by some (Dooley *et al.* 2021).

Distributing global mitigation effort according to either cost-effective or fair-share principles are not the only ways that could be used to inform how global emissions reductions could be translated to the national level in line with the Paris Agreement. For example, considerations of how NDCs align with sustainable development and efforts to eradicate poverty could also be included (Kikstra *et al.* 2021; Soergel *et al.* 2021). The purpose of this section is not to advocate for a specific implementation of any given approach over another or to claim that any of them are correct, but merely to present illustrative findings regarding mitigation "landing zones" for 2030 and 2035 for the G20.

5.2.1 Illustrative findings for G20 members based on top-down approaches

This section shows possible ranges of ambition for the G20 as a group based on a possible implementation of allocating global emissions to this block, applying cost-effective and fair-share principles. As the G20 remains a very heterogeneous group of countries, the results for this group of countries as a whole cannot be directly applied to any of the individual G20 members.

To produce cost-effective ambition ranges, the global 1.5°C and 2°C compatible pathways as assessed in chapter 4 are downscaled from the regional to the national level using a methodology developed under the Climate Action Tracker (Climate Action Tracker 2023b). The same classification as used in chapter 4 to define 1.5°C and 2°C compatible pathways has been used (see appendix D, available online, for further details on the methodology).

Meanwhile, to produce fair-share ambition ranges, equity pathways from the literature that cover all G20 members are considered (Baer *et al.* 2008; Höhne and Moltmann 2008; Höhne and Moltmann 2009; Holz, Kartha and Athanasiou 2018; Robiou du Pont *et al.* 2017). While a broader range of literature on equity approaches exists (Chakravarty *et al.* 2009; Pan *et al.* 2017; van den Berg *et al.* 2020; Winkler *et al.* 2011), very few papers cover all G20 countries and those that do not were excluded from this analysis. The literature is complemented with implementations of the major equity approaches produced by the Climate Action Tracker.[1] Together, the approaches cover all equity categories defined in Höhne, den Elzen and Escalante (2014), except the category solely based on cost-effectiveness, which is presented separately. The selected principles are all consistent with the principle of common but differentiated responsibilities and respective capabilities in the light of national circumstances and the Paris Agreement (Rajamani *et al.* 2021) and capture the major equity approaches considered in the literature.

It is important to highlight the assumptions around how global emissions reductions are translated to the national

1 In this chapter, we use input data from the Climate Action Tracker, but do not follow the Climate Action Tracker's methodology of synthesizing this data into an ultimate result. For more details, see appendix D.

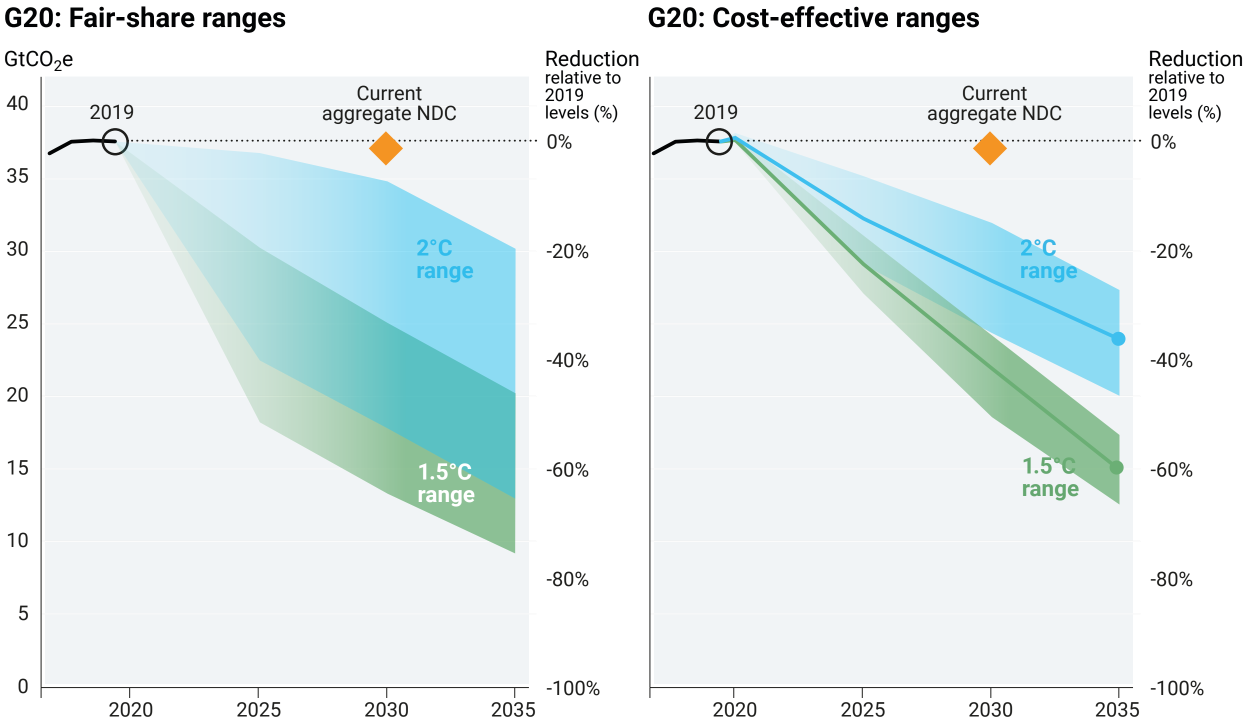
level when performing such an exercise, particularly around space, time and equity (Lecocq and Winkler 2024). For more detail on the methods used, see appendix D.

Given the challenges and uncertainties around aligning estimates of land use, land-use change and forestry (LULUCF) emissions between national greenhouse gas (GHG) inventories and models (Gidden *et al.* 2023; Grassi *et al.* 2021; chapter 2; chapter 4) and the lack of literature on how LULUCF emissions could be allocated across countries on the basis of equity, this analysis excludes LULUCF emissions. As a result, the global benchmarks – against which these results should be compared – shift. When excluding LULUCF emissions from the pathways, median 1.5°C compatible emissions reductions are 37 per cent and 50 per cent relative to 2019 by 2030 and 2035 respectively, and 2°C compatible emissions reductions are 20 per cent and 30 per cent in 2030 and 2035. These reductions are lower than those presented in chapter 4, as it is cost-effective to cut LULUCF emissions faster than the global average. However, the underlying set of pathways used are the same.

Figure 5.1 shows the results for the G20 as a group, and provides an overview of the indicative ambition ranges for 2030 and 2035 under the different ways to distribute mitigation effort applying fair-share and cost-effective principles, and comparing this with the global benchmarks.[2]

2 Data in this section is provided in the IPCC's Fourth Assessment Report (AR4) GWP100 global warming potentials (GWPs). However, the results would be broadly similar if AR6 GWP100 potentials were used instead. For the 1.5°C compatible pathways, moving from AR4 to AR6 GWPs increases the estimate of global emissions by ~1 per cent in 2030. However, as the estimate of historical emissions is also increased, the relative reduction in GHGs from a 2019 baseline remains broadly unchanged, still at 37 per cent for the 1.5°C compatible pathways (when excluding LULUCF from the range).

Figure 5.1 Illustrative fair-share and cost-effective mitigation ranges consistent with different temperature limits for the G20 collectively excluding the African Union



Reduction ranges by country groups and approaches relative to 2019 levels					
		2°C range		1.5°C range	
Country group	Approach	2030	2035	2030	2035
World average		-20% (-13 to -28%)	-30% (-22 to -37%)	-37% (-31 to -46%)	-50% (-45 to -58%)
G20	Fair-share	-8 to -56%	-21 to -70%	-35 to -69%	-49 to -81%
	Cost-effective	-23% (-14 to -32%)	-34% (-25 to -43%)	-38% (-32 to -46%)	-55% (-49 to -61%)

Note: All reductions are given relative to 2019 emissions, excluding LULUCF. Fair-share ranges shown give the minimum and maximum of the fair-share range, which therefore includes all the equity approaches assessed here. Cost-effective and global ranges show the median, and the twentieth to eightieth percentiles (in line with chapter 4).

Figure 5.1 shows the future emissions that would be consistent with limiting warming to 1.5°C with no or low overshoot, as well as limiting warming to 2°C with a 66 per cent chance. The definition of 1.5°C and 2°C pathways are equivalent to those used in chapter 4.

The first panel shows the ambition which could align with the range of equity approaches included in the analysis. The graph shows the full range produced by these approaches. The second panel shows the range of ambition that arises from the cost-effective pathways, highlighting the median and the twentieth to eightieth percentiles. The figure also shows the aggregate level of ambition reflected in current NDC for 2030 of the G20 collectively.[3]

As shown in figure 5.1, collectively the G20 would need to cut emissions faster than the global average under both approaches. Even at the least ambitious end of the fair-share range, the G20's emission reductions would only just align with the global average. And at the most ambitious end of the fair-share range, the G20 would need to cut emissions by just over 80 per cent by 2035 excluding LULUCF, substantially ahead of the global average. Median cost-effective emissions reductions of the G20 collectively would need to reach 38 per cent in 2030 and 55 per cent in 2035 relative to 2019 to align with 1.5°C pathways. The G20 has a key responsibility to accelerate emissions reductions as part of closing the global emissions gap.

There is no single definition of what represents a fair or cost-effective distribution of future emissions. As such, both the fair-share and cost-effective distributions reflect a range of possible future G20 emissions. In the fair-share panel of figure 5.1, the range represents results of different possible equity approaches which could be used to distribute emissions, and different possible implementations of these approaches. In the cost-effective panel, this represents differences in scenario design, input assumptions and model structure in the underlying integrated assessment models which produce these scenarios.

Different equity approaches imply different distributions of mitigation effort. Importantly, if one country or group of countries target the less ambitious end of their fair-share range, this leaves less flexibility for others, if total aggregate emissions are still to align with the global temperature goal. If the G20 goes beyond the minimum of its fair-share range, this can provide other lower-income regions and nations (including African Union members beyond South Africa) with more flexibility to reduce emissions at a slower pace.

The G20 remains a very heterogeneous country grouping, and the cost-effective and fair-share ranges for any individual country could differ strongly from the aggregate. For some countries, under any equity principle, their fair share could substantially exceed their cost-effective range. In such cases, it may not be feasible to align with their fair share by domestic mitigation action alone, and international mitigation support and co-operation will be essential to achieve robust alignment with the Paris Agreement's long-term temperature goal. This could be in the form of enhanced climate finance to catalyse emissions reductions in countries where their cost-effective potential goes beyond their fair-share range (Pachauri *et al.* 2022). For these countries, setting high-ambition conditional NDCs could help bring clarity to what they consider their fair share of future emissions, and what additional action could be achieved contingent on means of implementation, including international climate finance.

5.3 Emerging findings based on bottom-up national mitigation scenarios indicate that it is possible to accelerate action and increase ambition

National decarbonization scenarios that achieve national development priorities alongside ambitious mitigation action are emerging in many countries. Here, a few examples are presented to illustrate that it is possible – both for G20 members that have peaked emissions and those who are yet to peak – to reduce emissions beyond the levels implied by their current NDC targets, and to commit to and realize far higher national ambitions for 2035.

The top-down approaches of section 5.2, have the advantage of ensuring alignment with a global temperature limit, but their ability to capture country-level context is more limited. Country-level modelling does generally not ensure alignment with a global benchmark, but has the potential to better represent the specific context and dynamics at the national level, and to provide granular insights on implementation pathways to achieve ambition targets. Comparing results from national studies and top-down approaches can help shed light on the feasibility of different ambition brackets at the national level and the compatibility of national scenarios with different top-down approaches.

Available national-level scenarios use a wide range of targets and assumptions regarding the emissions reductions to be achieved. For example, some national scenarios take existing NDC targets set at the national level as their starting point, in some cases combined with key sectoral benchmarks to inform scenario design, such as achieving net-zero carbon dioxide (CO_2) emissions by a certain year (Waisman *et al.* 2019). Others use equity considerations such as the emissions budget available to a given country under certain equity approaches (Marquard *et al.* 2022).

For China, national modelling studies of mitigation pathways aligned with China's long-term decarbonization goal (He *et al.* 2021) and with interpretations of Paris alignment (He *et al.* 2021; Myllyvirta 2024; Wang 2021) indicate that it would be possible to reduce its CO_2 emissions by at least 10 per cent in 2030, and 28–37 per cent in 2035, relative to base years ranging from 2020 to 2023 to peak year. There are only small variations in estimates including and excluding LULUCF.

3 We take the quantification of G20 members' NDCs from chapter 3, and correct to remove LULUCF from these estimates, using data from the Climate Action Tracker to estimate the level of LULUCF that could be included in country NDCs.

For the United States of America, a bottom-up assessment by the University of Maryland employed an integrated assessment model with state-level detail to analyse sectoral decarbonization potentials based on existing and plausible policies from both federal and non-federal actors (e.g. including the Inflation Reduction Act, other federal regulations and state-level policies such as renewable portfolio standards). The scenarios estimate that the United States of America could achieve net GHG emissions reduction of 65 per cent (range of 59–71 per cent) by 2035, relative to 2005 levels (Zhao *et al.* 2024a; Zhao *et al.* 2024b).

For some countries with large net positive or negative LULUCF emissions, such as Brazil and Indonesia, results are highly dependent on whether LULUCF emissions are considered (Svensson *et al*. 2023). For Brazil, a scenario that achieves the 2030 NDC target and reaches net-zero GHG emissions before 2050 only using already commercially available technologies (no carbon capture and storage or technologies in research and development stages) reduces GHG emissions in 2035 by 60 per cent relative to 2019 levels including LULUCF, but only by 2 per cent when LULUCF is excluded (La Rovere *et al.*, 2024). The difference underscores that most of the mitigation efforts under this scenario comes from changes in land use and forestry, primarily by halting and reversing deforestation, which is in line with the outcome of the global stocktake on conserving, protecting and restoring nature and ecosystems (UNFCCC 2024, para. 33).

In the Deep Decarbonization Pathways initiative (Institute for Sustainable Development and International Relations 2024), benchmarks from global scenarios are applied to help inform the consistency of the national models with global decarbonization goals (Bataille *et al.* 2020; Waisman *et al.* 2019). Recent Deep Decarbonization Pathways scenarios have been developed by Argentina, Brazil, China, India, Indonesia, Mexico, Nigeria, South Africa and the United States of America. They demonstrate the feasibility of reaching emission levels by 2030 and 2035 that put countries on track for achieving national carbon neutrality at dates corresponding to current commitments by each country (IDDRI 2024). Emission ranges from these national scenarios in 2030 and 2035 display a large variability as a logical consequence of the diversity of country circumstances and target dates for carbon neutrality (between 2050 and 2070 across the countries listed above), which lead to very diverse emission profiles towards carbon neutrality. However, these national-level studies confirm that it is possible both for countries that have peaked emissions and those that have not yet peaked their emissions to go further and faster in terms of mitigation action and ambition than implied by their existing NDC targets.

Cross-cutting analysis of the country scenarios can furthermore reveal key drivers of emission reductions by 2030 and 2035 to align the ambition and action of countries with the temperature goal of the Paris Agreement. National pathways to net zero highlight power generation, passenger transport and LULUCF sectors as holding the highest potential for short-term emission reductions across countries, confirming the results of the updated assessment of emission reduction potentials for 2030 and 2035 of chapter 6. In these sectors, technical solutions are largely available, and the scenario analysis highlights that the needed acceleration of their diffusion requires adequate measures on the enabling environment, considering country circumstances. In the power sector, this notably concerns adapting the rules of the power markets, such as facilitating private investments, ensuring efficient governance of permitting processes and enforcement of renewable quotas or providing penalties for non-compliance. In the passenger transport sector, measures include support to lower purchase prices for electric vehicles (and therefore enhanced access for low- and middle-income households) and targeted measures in favour of non-motorized and public transport, such as the revision of public road space allocation between modes and speed limits to increase safety and favour the more efficient mobility choices. Finally, in the LULUCF sector, short-term emission reductions could be achieved by strengthening the implementation of current policies already in place to reduce deforestation and avoid peatland degradation, as well as increases in the CO_2 absorption from re- and afforestation.

6 Bridging the gap: Sectoral transformation benchmarks, mitigation potentials and investment needs

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6.1 Introduction and synthesis

Bridging the emissions gap will require simultaneous and immediate transformations across all sectors of the economy. The global stocktake outcome highlights some of these transformations and calls on countries to contribute in a nationally determined manner to several sector-specific global mitigation efforts, including the tripling of renewable energy capacity and doubling of the global average annual rate of energy efficiency improvements by 2030, transitioning away from fossil fuels in energy systems and conserving, protecting and restoring nature and ecosystems (United Nations Framework Convention on Climate Change 2023, paragraph 28; see also chapter 1).

However, in the context of preparation for nationally determined contributions (NDCs), it can be challenging to understand how global milestones and sector-specific mitigation efforts translate to national interventions (see also chapter 5). To help inform the preparation of the next NDCs, this chapter focuses on answering the following three questions for 2030 and 2035:

- What are the critical global sectoral transformation benchmarks to which the next NDCs should contribute? (Section 6.2.)
- Where and what are the main opportunities for reducing emissions and bridging the emissions gap? (Section 6.2.)
- What are the implications for investment needs and sources of finance? (Section 6.3.)

6.1.1 High-level synthesis: Can the gap be bridged?

The challenge of bridging the emissions gap in 2030 and 2035 (chapter 4) is indisputable, as is the task of transforming the energy, agriculture and land-use, transportation, industry, buildings and other sectors. At the same time, opportunities abound for accelerating mitigation action alongside achieving pressing development needs and Sustainable Development Goals.

Key, near-term benchmarks for sectoral transformation are summarized in table 6.1 (see appendix E, available online). These sectoral benchmarks indicate the levels of action needed to limit warming to 1.5°C while pursuing development goals, and accordingly provide a near-term road map for achieving the Paris Agreement's temperature goal. For example, they indicate how fast fossil fuels need to be phased down, renewable power scaled up and deforestation effectively halted. Global progress against all the benchmarks covered is limited. A recent study (Boehm *et al.* 2023) found that only 1 of the 42 assessed sector benchmarks was on track for 2030 (the share of electric vehicles in light-duty vehicle sales); 6 indicators were off track but headed in the right direction; 24 indicators were well off track, although headed in the right direction; 6 indicators were headed in the wrong direction altogether; and five indicators lacked sufficient data to determine progress. The next round of NDCs presents an opportunity for countries to adopt more ambitious sectoral targets and accelerate implementation. Recent successes, such as the rapid cost reductions in and uptake of renewable energy technologies across diverse countries like Denmark, Lithuania and Uruguay (box 6.1; Jaeger 2023a), as well as the rapid uptake of electric vehicles, including in Belgium, China, Finland, Iceland, Norway and Sweden (box 6.2; International Energy Agency [IEA] 2024a), highlight how change can unfold more quickly than anticipated. But such successes should be rapidly scaled up across regions.

The updated assessment of sectoral mitigation potentials in this chapter underscores that there is ample opportunity to accelerate mitigation action both by 2030 and by 2035. The global potential to reduce sectoral emissions is estimated at 31 gigatons of carbon dioxide equivalent ($GtCO_2e$) per year in 2030 (range: 25–35) and 41 $GtCO_2e$/year in 2035 (range: 36–46) for mitigation measures up to US$200/$tCO_2e$, which, if fully implemented, would be more than sufficient to bridge the emissions gap (figure 6.1; table 6.2). Sectoral emission reduction estimates provide policymakers with a clear and granular view of where important emission reduction options exist, that can be explored in specific national contexts as part of the next NDCs.

Remarkably, just two proven and cost-competitive options, solar photovoltaics (PV) and wind energy, make up 27 per cent of the total emission reduction potential in 2030 and 38 per cent in 2035. In forestry, reduced deforestation, increased reforestation and improved forest management present readily available options with large emission reduction potentials of about 19 and 20 per cent of the total potential in 2030 and 2035 respectively. Other important and readily available mitigation options include demand-side measures across all sectors, and efficiency measures, electrification and fuel switching in the buildings, transport and industry sectors. Demand-side measures are important for enabling and/or supplementing supply-side measures (e.g. shifting to sustainable healthy diets and reducing food waste reduces deforestation and non-CO_2 emissions in agriculture).

Although these measures are available to generate emission reductions in the near term, there are other important measures that will require longer lead times yet are critical for deep decarbonization in the future and avoiding carbon lock-in now (e.g. improving industrial processes, the efficiency and materials of new buildings, transportation infrastructure and some CO_2 removal technologies).

Mitigation measures are primarily driven by development and can be achieved along with economic, social and environmental benefits and help deliver on the Sustainable Development Goals at both the local and global levels. In addition to avoiding the increasingly severe impacts of climate change and resulting global losses and damages to infrastructure, the food system, natural ecosystems, and human lives and well-being – such as the projected US$38 trillion cost of damages in 2050 under a 3°C temperature rise scenario (Kotz, Levermann and Wenz 2024) – climate mitigation measures in forests and other ecosystems, agriculture, energy, transport, buildings, industry and waste can generate local cost savings and more jobs, improve air, water and soil quality, and enhance resilience to climate change, biodiversity and human health (Intergovernmental Panel on Climate Change [IPCC] 2023). Demand-side interventions and ecosystem conservation and restoration provide particularly high socioeconomic and environmental co-benefits (IPCC 2023). Mitigation measures designed and deployed in response to the needs of multiple stakeholders and which maximize co-benefits and reduce potential trade-offs have a much higher chance of being successful and scaled up (Shukla *et al.* eds. 2022).

It is estimated that about half of the mitigation potential can be achieved at relatively low costs (<US$20/$tCO_2e$), as per the IPCC conclusion (Shukla *et al.* eds. 2022). The most cost-effective measures include those that reduce consumption and waste and enhance efficiency (across all sectors), solar PV and wind energy deployment, and reduced deforestation and ecosystem conversion, with modest cost developments expected in the near term. For solar and wind energy, further cost declines can be expected, although this may be partly offset by the additional costs of integrating high shares of variable energy sources into power systems (Brown *et al.* 2018; IEA 2024a). Electrification, for example in transport, can also lead to lower costs. In the industry sector we see a higher emission reduction potential; industrial facilities typically take 5–10 years to plan, permit, finance and build, so larger near zero emitting potentials become possible in the early to mid-2030s. However, this higher emission reduction potential comes with a modest shift to higher-cost categories.

There are only six years left until 2030. With some exceptions,[1] it is estimated that a considerable share of the potential could still be feasible by 2030, but this depends on immediate and dramatically increased global-scale action. However, consistent with the findings in chapter 4, delayed action substantially reduces mitigation potentials and their feasibility. For example there is 7 $GtCO_2e$ less potential in 2030 assessed in this report compared with the IPCC *Sixth Assessment Report* (AR6) (Shukla *et al.* eds. 2022) (table 6.2) primarily due to the time needed for implementation, increased locked-in emissions and additional mitigation already factored into the current policy baseline. Realizing the potentials in 2035 therefore relies on upscaling achieved mitigation from 2030.

There are also many barriers that hinder the rapid deployment of mitigation measures, including perverse subsidies and incentives, and the necessary enabling environment including, among others, regulatory and governance reforms, infrastructure, technology development and transfer, technical capacity, and investment. Various studies have shown that effectively realizing mitigation potentials and closing the emissions gap requires rapid and decisive policy action globally, employing a whole-of-government approach that emphasizes sustainable and climate-resilient development, effectively addresses barriers and catalyses public and private sector action (Shukla *et al.* eds. 2022). Action will need to go far beyond relying on a single government agency (e.g. environmental ministry), a single sector (e.g. power), or a single policy instrument (e.g. carbon pricing) to enable the deep decarbonization needed (Fazekas, Bataille and Vogt-Schilb 2022).

Meeting investment needs, particularly in emerging market and developing economies (EMDEs), presents both a pressing challenge and a significant opportunity for growth and development. While the required scale of investment (an estimated increase of US$6.7 trillion to US$11.7 trillion annually by 2035) may seem daunting, most of this involves shifting existing capital flows from high- to low-carbon activities, with global incremental investment for a net-zero transition estimated at US$0.9 trillion to US$2.1 trillion per year between 2021 and 2050. With the right policy frameworks, institutional structures and financial tools in place, this transition is financially feasible in the broader context of the US$110 trillion global economy.

6.2 Sector transformations, benchmarks and potentials can guide the next NDCs

6.2.1 Approach and overview of results

Methodology for benchmarking

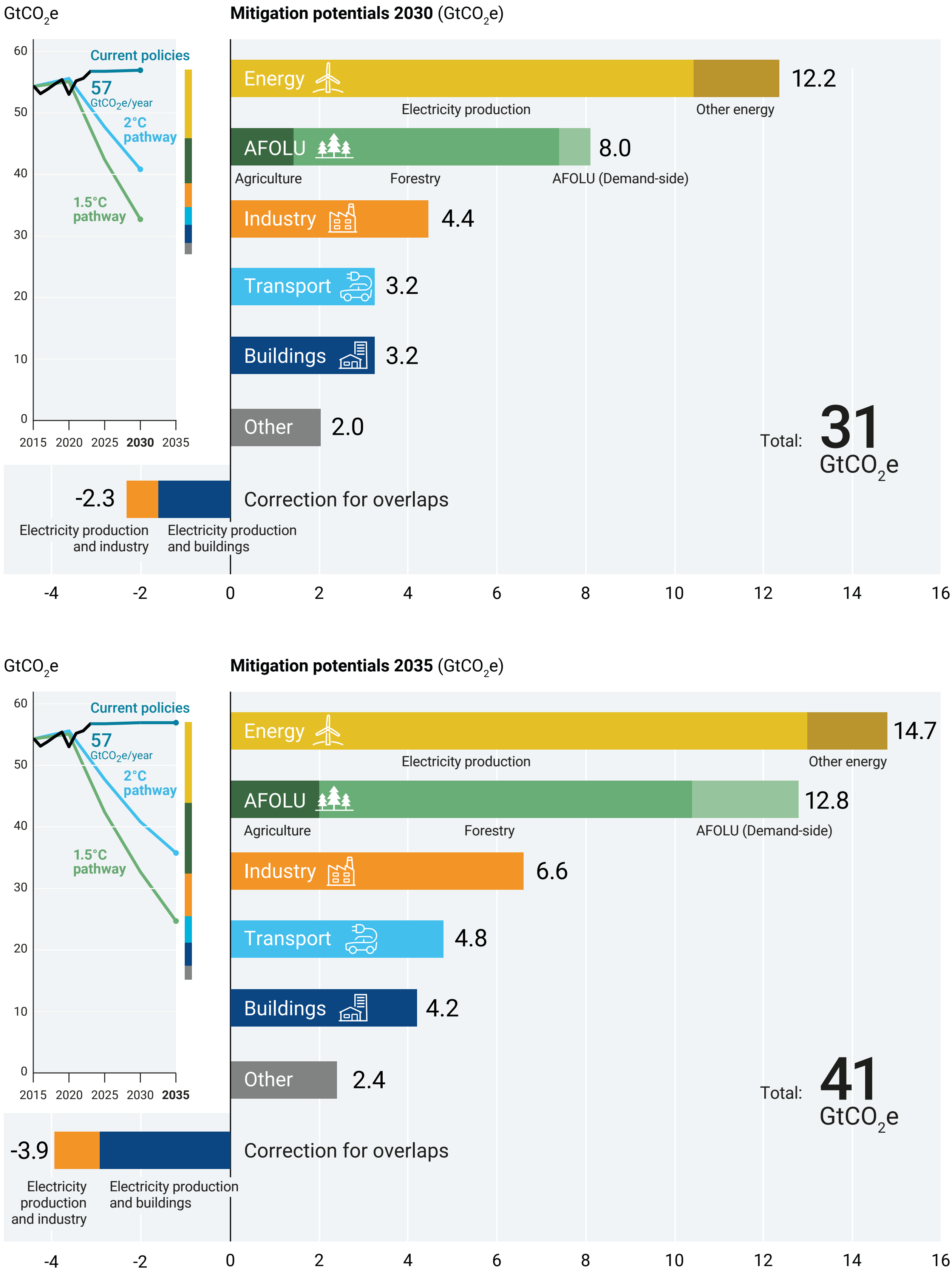
This chapter summarizes the existing global sectoral benchmarks (presented in table 6.1 and appendix E)[2] that are stated to be aligned with a 1.5°C pathway and are timebound for 2030 and/or 2035. Benchmarks included in this chapter are not exhaustive of all the transformational changes needed to limit warming to 1.5°C. Rather, they illustrate a subset of key levers that, collectively, can help deliver this Paris Agreement temperature goal. The inclusion of benchmarks is limited to those that were featured in peer-reviewed literature published between January 2019 and August 2024, as well as those that were expressed as concrete, actionable indicators capable of measuring the implementation of sectoral transformations in practice. The primary sources from which most benchmarks were derived include modelled pathways from integrated assessment models, bottom-up modelling studies that identify sector-specific mitigation road maps, and bottom-up assessments of technical and cost-effective mitigation potential. Accordingly, definitions, assumptions and optimizations vary, as do the resulting temporal and spatial distributions of mitigation efforts.

As highlighted in chapter 5, such approaches do not necessarily account for equity and principles of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. Applying them to the national level would require such considerations, and may need to be adapted for national contexts considering equity, feasibility and other factors. It will also be necessary to consider how each country can contribute its highest possible ambition to the sectoral transformations.

1 Examples of these are options that have long project implementation times (like nuclear power plants) and options that rely on replacement of the capital stock (e.g. new buildings that are not constructed in an energy-efficient way will be difficult to retrofit).

2 Table 6.1 provides a simplified summary of global, sectoral benchmarks further detailed in appendix E. Notably, this table includes indicators for which more than one set of 2030 and/or 2035 benchmarks were published by different sources, while appendix E features a broader list of sectoral benchmarks, including underlying sources and notes. Exceptions were made to include indicators for which benchmarks from just one source were available for indicators that track progress towards critical shifts that would otherwise not be represented (e.g. modal shifts in the global transport sector).

Figure 6.1 **Overview of annual mitigation potentials by 2030 and 2035 by sector up to US$200/t$CO_2$e**



Note: Annual mitigation potential estimates ($GtCO_2e$/year) for each sector represent those available under US$200/t$CO_2$e. The aggregate sector estimates are corrected to reduce potential overlaps. Due to rounding, there is a small difference in the sum of the aggregated sectoral potentials (including the corrections for overlaps) and the total mitigation potential.

Table 6.1 Global sectoral benchmarks for 2030 and 2035 aligned with 1.5°C pathways

This table summarizes a range of 1.5°C-aligned sectoral benchmarks from select sources, but it is not comprehensive, and the sources are not necessarily comparable, as they vary in their assumptions. Therefore, the ranges below should not be interpreted as inclusive of all possible benchmarks compatible with achieving a 1.5°C-aligned future. The most recent historical data point, as well as the year for which data are available, vary by source. Ranges below indicate both the years for which data are available and their values, but the lower and upper bounds of the range do not always correspond with one another. Values were rounded to two significant figures; deviations from this approach were made only in instances in which rounding loses nuance. Percentage changes relative to the most recent historical data point that are higher than +/-1,000 per cent are noted as > +/1,000 per cent to communicate the order of magnitude of distance from the benchmark without conveying false precision.

Indicator	Most recent historical data point from benchmark source (year)	2030 benchmark		2035 benchmark	
		Absolute value	Percentage change relative to most recent historical data point	Absolute value	Percentage change relative to most recent historical data point
Power					
Share of zero-carbon sources in electricity generation (%)	37–40 (2019–2023)	65–91	+73% to +133%	77–96	+110% to +150%
Renewable power capacity (TW)	3.4–3.9 (2022–2023)	11–12	+180 to +253%	18	+400 to +430%
Share of wind and solar in electricity generation (%)	9–14 (2020–2023)	43–78	+210% to +500%	59–86	+320% to +560%
Share of unabated coal in electricity generation (%)	34–36 (2020–2023)	3–13	-64% to -91%	0–3	-92% to -100%
Share of unabated fossil gas in electricity generation (%)	22–24 (2020–2023)	5–16	-27% to -78%	2–7	-71% to -92%
Industry					
Share of electricity in the industry sector's final energy demand (%)	29 (2022)	35–43	+21 to +48%	43–46	+48 to +59%
Carbon intensity of global cement production ($kgCO_2$/t cement)	580–660 (2020–2022)	360–600	-3.2% to -45%	490	-21%
Carbon intensity of global steel production ($kgCO_2$/t crude steel)	1,400–1,900 (2021–2023)	960–1,350	-24% to -36%	590	-61%
Green hydrogen production (Mt)	0.027 (2021)	58[a]	>+1,000%	N/A	N/A
Agriculture, forestry and other land use (AFOLU)					
Deforestation (Mha/year)	5.4 (2023)	1.9	-65%	0 to 1.5	-72%
Peatland degradation (Mha/year)	0.06 (annual average, 1993–2018)	0	-100%	0	-100%
Mangrove loss (ha/year)	32,000 (annual average, 2017–2019)	4,900	-85%	4,900	-85%
Avoided loss of forests and wetlands (total Mha)	N/A	45 Mha	Insufficient data	N/A	N/A
Reforestation (total Mha)	130 (total gain, 2000–2020)	100 (2020–2030)[b]	+77%	150 (2020–2035)[b]	+115%

Indicator	Most recent historical data point from benchmark source (year)	2030 benchmark		2035 benchmark	
		Absolute value	Percentage change relative to most recent historical data point	Absolute value	Percentage change relative to most recent historical data point
Peatland restoration (total Mha)	0 (as of 2015)	15 (2020–2030)[b]	>+1,000%	16 (2020–2035)[b]	>+1,000%
Mangrove restoration (total ha)	15,000 (total direct gain, 1999–2019)	240,000 (2020–2030)[b]	>+1,000%	N/A	N/A
Greenhouse gas (GHG) emissions intensity of agriculture (gCO_2e/1,000 kcal)	690 (2021)[a]	500	-28%	450	-35%
Livestock methane emissions ($GtCO_2e$/year)	3.1 (2021)	2.3	-25%	N/A	N/A
Crop yields (t/ha)	6.7 (2022)	7.8	+16%	8.2	+22%
Ruminant meat productivity (kg/ha)	29 (2022)	33	+14%	35	+21%
Share of food production lost (%)	13 (2021)	6.5	-50%	6.5	-50%
Food waste (kg/capita)	130 (2022)	61	-53%	61	-53%
Ruminant meat consumption in high-consuming regions (kcal/capita/day)	100 (2022)	79[c]	-21%	74[c]	-26%
Transport					
Number of kilometres of rapid transit per 1 million inhabitants (km/1M inhabitants)	20 (2021)	38	+90%	N/A	N/A
Number of kilometres of high-quality bike lanes per 1,000 inhabitants (km/1,000 inhabitants)	0.0044 (2020)	2	>+1,000%	N/A	N/A
Share of kilometres travelled by passenger cars (% of passenger-km)	45 (2019)	35–43	-4% to -22%	N/A	N/A
Share of electric vehicles in light-duty vehicle (car and van) sales (%)	12–16 (2022–2023)	66–95	+270% to +690%	98 to 100	+440% to +730%
Share of electric vehicles in the light-duty vehicle (car and van) fleet (%)	2.2 (2023)	20–40	+810% to >+1,000%	N/A	N/A
Share of electric vehicles in two- and three-wheeler sales (%)	13–47 (2022–2023)[d]	78–85	+81% to +500%	100	+530% to +670%
Share of battery electric vehicles and fuel cell electric vehicles in bus sales (%)	3.1–4 (2022–2023)	56–60	>+1,000%	90	>+1,000%
Share of electric vehicles in medium- and heavy-duty commercial trucks (%)	1 (2022–2023)	30–37	>+1,000%	65	>+1,000%
Share of sustainable aviation fuels in global aviation fuel supply (%)	0.1 (2022)	13	>+1,000%	28–32	>+1,000%
Share of zero-emissions fuels in maritime shipping fuel supply (%)	0 (2018)	5	>+1,000%	N/A	N/A
Buildings					
Energy intensity of building operations (kWh/m^2)	150 (2022)	85–120	-17% to -41%	N/A	N/A
Carbon intensity of building operations ($kg\ CO_2/m^2$)	38 (2022)	13–16	-58% to -66%	N/A	N/A

Indicator	Most recent historical data point from benchmark source (year)	2030 benchmark		2035 benchmark	
		Absolute value	Percentage change relative to most recent historical data point	Absolute value	Percentage change relative to most recent historical data point
Retrofitting rate of buildings (%/year)	<1 (2019)	2.5–3.5	>+150% to +250%	2.5–3.5	>+150% to +250%
Share of new buildings that are zero-carbon in operation (%)	5 (2020)	100	>+1,000%	100	>+1,000%
Novel CO_2 removal					
Novel CO_2 removal ($MtCO_2$/year)	0.57–2.0 (2022–2023)	30–800	>+1,000%	150–1,700	>+1,000%
Cross-cutting					
Global fossil fuel supply for all energy and non-energy uses	480–510 (2019–2022)	330–360	-29% to -30%	240–280	-42% to -53%

a. This benchmark refers to what is needed for the whole economy to decarbonize, rather than the industry sector alone.

b. Reforestation, peatland restoration and mangrove restoration benchmarks are additional to any reforestation and restoration that occurred prior to 2020, and these benchmarks are cumulative from either 2020 to 2030 or 2020 to 2035.

c. This benchmark applies specifically to regions with high ruminant meat consumption (primarily the Americas, Europe and Oceania). It does not apply to populations within high-consuming regions that already consume less than 60 kcal/capita/day of ruminant meat, have micronutrient deficiencies and/or do not have access to affordable and healthy alternatives to ruminant meat.

d. The discrepancy between the Bloomberg New Energy Finance (BloombergNEF) data used by Boehm *et al.* (2023) and the data published by IEA (2024a) stems from definitional disagreement. IEA defines two-wheelers as vehicles with a top speed of at least 25 kph and which fit the L1 and L3 classes definition of the United Nations Economic Commission for Europe. This excludes micromobility options such as electric-assisted bicycles and low-speed electric scooters. The BloombergNEF data incorporated into Boehm *et al.* (2023) include lower-speed electric mopeds and scooters.

Methodology for sectoral mitigation potentials

Sectoral mitigation potentials are the quantity of GHG emission reductions or removals that can be achieved by a given mitigation measure in a specific period relative to specified emission baselines (Shukla *et al.* eds 2022). They can be estimated as the amount possible given the current technology (technical potential), with cost constraints (economic potential) or with other political and sustainability constraints. When added up, and adjusting for any overlaps, these estimates give an indication of the total potential for reducing global GHG emissions in 2030 and 2035. The total potential can then be compared with current policies projections and the scenarios of chapters 3 and 4 to determine whether the emissions gap can be bridged, thereby providing policymakers with a granular view of where important emission reduction options exist that can inform the preparation of the next NDCs.

This chapter assesses the techno-economic potentials for mitigation options available up to US$200/$tCO_2e$, considering internal monetary costs and savings (e.g. costs of equipment and benefits due to saved energy), but excluding external costs and benefits, like the costs due to climate change impacts. It builds on and updates earlier efforts (United Nations Environment Programme [UNEP] 2017; Shukla *et al.* eds. 2022) estimating mitigation potentials in 2030, and provides estimated potentials in 2035 to help inform the next NDCs that will include mitigation targets for 2035. The cut-off level of US$200/$tCO_2e$ was chosen as there are some potentially important options in the range between US$100 and US$200/tCO_2e (Shukla *et al.* eds. 2022, table 12.3). However, it is estimated that about half of the mitigation potential can be achieved at costs below US$20/$tCO_2e$ (Shukla *et al.* eds. 2022).[3] The cost analysis takes a social cost perspective, using a social discount rate. Cost levels are taken from the underlying studies as reported.

The mitigation potential assessment relies on many underlying literature sources, mostly with a focus on specific sectors, options or technologies. Each source has its own approach and methodology, including the use of different baselines. Although studies may use

3 Cost thresholds beyond US$200/$tCO_2e$ were not explored as part of the assessment.

'current policies' or similar baselines, they can deviate from the median baseline reported in chapter 4 (e.g. 57 $GtCO_2e$ in 2035). Mitigation measures and their potentials cannot be simply added together because they may interact, overlap or compete with each other. A more detailed methodology is provided in a separate study (UNEP Copenhagen Climate Center [UNEP-CCC] and Common Futures 2024).

Table 6.2 Sectoral mitigation potentials in 2030 and 2035

Estimates represent annual potentials ($GtCO_2e$/year) available under US$200/$tCO_2e$; with uncertainty ranges in parentheses. The aggregated estimates are corrected to reduce potential overlaps. Due to rounding, there is a small difference in the sum of the aggregated sectoral potentials (including the corrections for overlaps) and the total mitigation potential.Industry estimates are corrected for autonomous energy efficiency improvements. Appendix E provides a more detailed list of mitigation measures and potentials, their sources and their comparison with the Emissions Gap Report 2017 and IPCC AR6 estimates. A detailed methodology on the aggregate estimates, as well as the calculations for each measure is provided in a separate study (UNEP-CCC and Common Futures 2024).

Mitigation potentials ($GtCO_2e$)	2030	2035
Total mitigation potential (range)	**31 (25–35)**	**41 (36–46)**
Emissions gap between current policies and 1.5°C pathways (range)	**24 (20–26)**	**32 (20–37)**
Emissions gap between current policies and below-2°C pathways	**16 (12–18)**	**21 (9–26)**
Energy sector aggregated (range)	**12.2 (8.8–14.2)**	**14.7 (13.2–16.2)**
Solar energy[i]	4.2	7.9
Wind energy[i]	4.2	7.7
Hydropower, nuclear power and geothermal power	1.4	2.4
Power production with bioenergy, bioenergy with carbon capture and storage (CCS), and CCS	0.6	1.5
Reduced methane emissions from fossil fuels production	1.9	1.7
AFOLU aggregated (range)	**8.0 (4.1–16.7)**	**12.8 (6.3–19.1)**
Agriculture (improved rice production, nutrient management, enteric fermentation, manure management, soil carbon management, agroforestry and biochar)	1.4	2.0
Forestry (reduced deforestation, afforestation/reforestation, and improved forest management)	5.9	8.4
Demand-side (reduced food waste, shift to sustainable healthy diets)	0.7	2.4
Buildings aggregated direct + indirect (range)	**3.2 (2.4–4.0)**	**4.2 (3.1–5.2)**
Avoid demand for energy services	0.6	0.8
New buildings (better insulation, efficient heating & cooling, renewables)	1.6	2.2
Retrofitting (better insulation, efficient heating & cooling)	0.3	0.3
Appliances[ii]	0.7	0.9
Transport aggregated (range)	**3.2 (1.6–4.8)**	**4.8 (2.4–7.2)**
Modal shift to public transport or (e-)bikes	1.1	1.4
Shift to electric vehicles[iii]	0.4	0.9
Other road transport (improved fuel efficiency and biofuels)	1.3	2.0
Shipping (energy efficiency and optimization, and a shift to low- and zero-emission fuels)	0.2	0.4
Reduced demand increase in aviation	0.4	0.5
Other aviation (energy efficiency and optimization, a shift to low- and zero-emission fuels, other)	0.2	0.4
Industry aggregated (range)	**4.4 (4.2–4.8)**	**6.6 (5.8–7.4)**
Energy efficiency[iv]	1.0	1.1
Material efficiency	0.7	1.2
Enhanced recycling	0.6	1.0

Mitigation potentials ($GtCO_2e$)	2030	2035
Total mitigation potential (range)	**31 (25–35)**	**41 (36–46)**
Emissions gap between current policies and 1.5°C pathways (range)	**24 (20–26)**	**32 (20–37)**
Emissions gap between current policies and below-2°C pathways	**16 (12–18)**	**21 (9–26)**
Fuel switching and electrification	1.6	2.1
Advanced feedstock decarbonization & process changes	0.7	1.2
Carbon capture utilization and CCS	0.1	0.5
Cementitious material substitution (e.g. 1/3 ground limestone & 2/3 calcined clays, replacing <=50% clinker)	0.3	0.4
Reduction of nitrous oxide emissions	0.2	0.3
Others aggregated (range)	**2.0 (1.2–2.5)**	**2.4 (1.9–2.9)**
Fluorinated gases	1.2	1.4
Reduced methane emissions from solid waste and wastewater	0.8	1.0
Direct air CCS and enhanced weathering	small	small
Correction for overlaps between sectors[v]	**-2.3**	**-3.9**
Electricity sector and Buildings	-1.6	-2.9
Electricity sector and Industry	-0.7	-1.0

i. Several studies suggest high solar PV and wind potentials could be achieved for 2035 (17–22 TW for solar PV; 10–13 TW for wind) and 2040 with extensive electrification of the energy system and significant expansion of the electricity grid (Jacobson *et al.* 2019; Breyer *et al.* 2020; Bogdanov *et al.* 2021). These higher potentials were excluded in determining the mitigation potential.

ii. Information from IEA (2024b) and UNEP (2023) suggests mitigation potential for appliances could be double of what is reported here, but due to unclear baselines these estimates were excluded.

iii. The emission reduction potential for electric vehicles may be higher than reported in this table. The mitigation potential is based on IEA's recent *Global EV Outlook* (IEA 2024a), which uses lower baseline emissions compared to chapter 4 of this report.

iv. Energy efficiency and some of the other options are partially market driven along with stock turnover, energy efficiency programmes and regulation. Therefore, the aggregate was corrected for this autonomous implementation, assumed to be 15 per cent of the total potential.

v. The total aggregated mitigation potential has been adjusted to account for potential interactions between sectors. The method used for correcting potential overlaps is detailed in chapter 3.3 of UNEP-CCC and Common Futures (2024).

Interpreting results and limitations

The global sectoral benchmarks and mitigation potentials presented in this chapter are not directly comparable. They were developed separately and rely on different methods, assumptions and data sources. Therefore, achieving a specific 1.5°C-compatible benchmark for 2030 and 2035 does not necessarily result in the realization of the full mitigation potential assessed for that same activity, and vice versa.

6.2.2 Energy sector

Sectoral transformation and benchmarks

Primary strategies for transforming the energy sector to rapidly reduce GHG emissions include: transitioning away from fossil fuels in electricity generation; scaling up zero-carbon electricity generation; modernizing power grids by expanding energy storage and managing power demand; and ensuring electricity access, as well as a just and equitable transition, for all (Shukla *et al.* eds. 2022; Boehm *et al.* 2023). Table 6.1, as well as appendix E, features 1.5°C-compatible benchmarks for 2030 and 2035 that specify the pace and scale of change needed to transform the power sector in the near term.

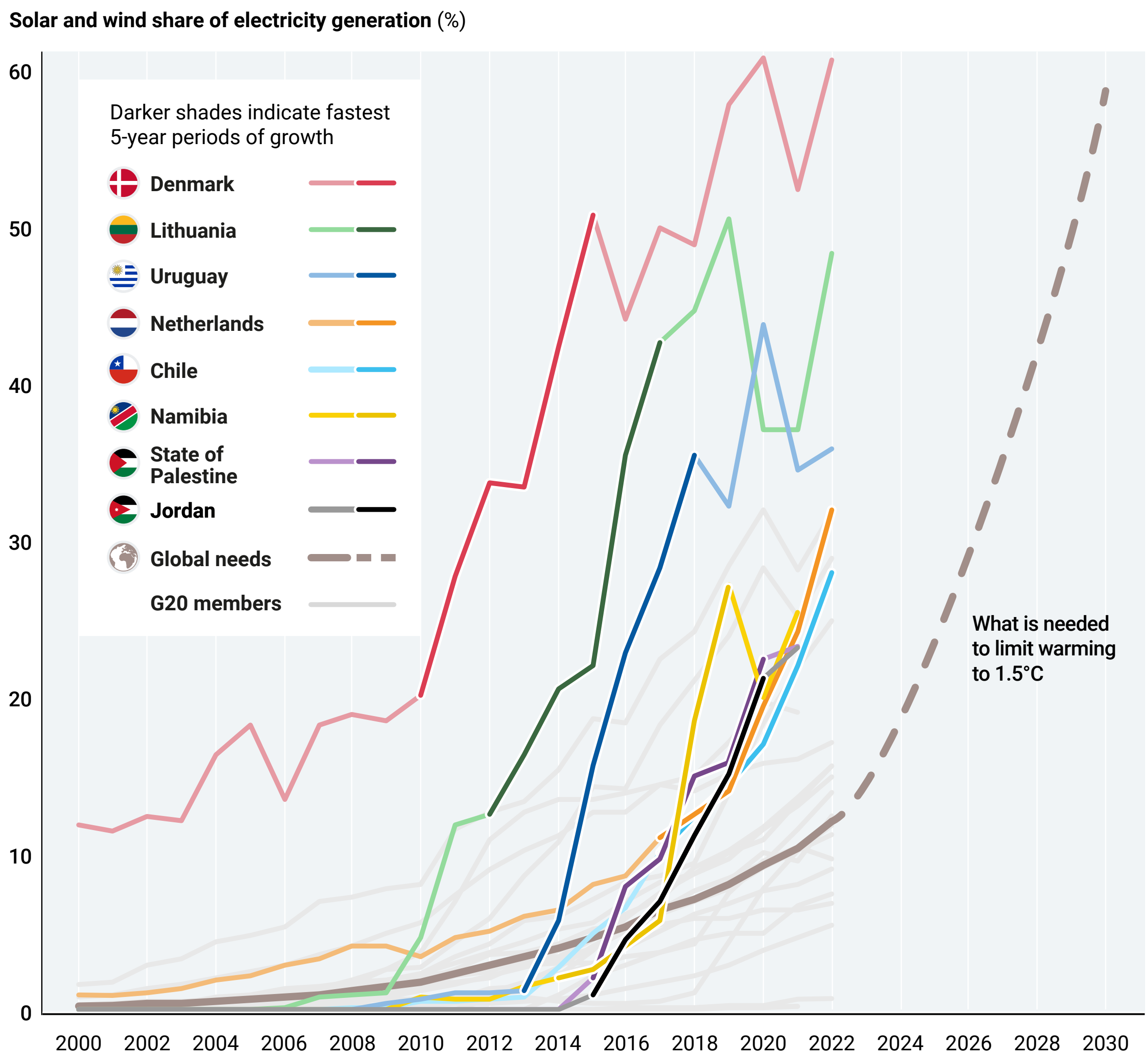
Rapidly transitioning away from fossil fuels, including unabated coal and gas, remains an urgent priority for this next generation of NDCs. But collective progress made towards these benchmarks continues to fall short of the action needed to limit warming to 1.5°C. By one estimate, global efforts to dramatically reduce electricity generation from unabated coal and fossil gas need to accelerate by sevenfold and more than tenfold, respectively, this decade (Boehm *et al.* 2023). Worldwide, the shift to zero-carbon power sources has fared better, with some countries seeing remarkable gains in wind and solar (box 6.1). But globally, increases in electricity generation from these sources are still not on track to decarbonize the power sector (Boehm *et al.* 2023).

Box 6.1 Examples of national efforts to scale up renewables and transition away from coal

Evidence from individual countries suggests that rapid change is possible. Denmark, Lithuania and Uruguay, for example, have seen a faster uptake of solar and wind as a share of total electricity generation than what is needed globally to meet 1.5°C-compatible benchmarks for 2030 (box 6.1; figure B6.1). These countries embraced a combination of policies, including both regulatory interventions and incentives, that enabled such positive changes (Jaeger 2023b). Similarly, China, the United States of America, Brazil, India and Germany have installed significant amounts of renewables in recent years, collectively comprising more than 60 per cent of total renewable power capacity in 2023 (International Renewable Energy Agency [IRENA] 2024). In turn, these advances have helped improve technologies and drive down their costs (Gielen *et al.* 2019).

At the same time, several countries have achieved impressive reductions in coal-fired power generation, illustrating that it is possible to rapidly transition away from these fossil fuels. One analysis of recent rates of coal phase-out, for example, finds that Greece and the United Kingdom transitioned away from coal at a faster rate than what is needed to meet global 1.5°C-compatible benchmarks for 2030 – from 36 per cent of electricity generation in 2022 to less than 4 per cent in 2030. Denmark, Spain, Portugal, Israel, Romania, Germany, the United States of America and Chile have also seen steep declines in recent years (figure B6.2) (Jaeger 2023a).

Figure B6.1 Fastest five-year periods of growth in the share of solar and wind in electricity generation



Source: Jaeger (2023b)

Figure B6.2 Fastest eight-year periods of reductions in the share of coal in electricity generation

Country	Fastest 8-year period of decrease	Decrease in coal power over 8-year period	Percentage point difference	Share of coal reductions replaced by zero-carbon power
Greece	2014–2022	51% → 10%	41 ↓	47%
United Kingdom	2012–2020	39% → 2%	37 ↓	76%
Denmark	2009–2017	49% → 20%	29 ↓	100%
Spain	2002–2010	34% → 9%	25 ↓	53%
Portugal	2012–2020	29% → 5%	24 ↓	66%
Israel	2006–2014	55% → 32%	23 ↓	7%
Romania	2012–2020	39% → 17%	22 ↓	90%
Germany	2012–2020	45% → 24%	21 ↓	79%
United States of America	2014–2022	39% → 19%	20 ↓	39%
Chile	2014–2022	41% → 23%	18 ↓	95%

What is needed to get on track for 1.5°C

Country	Period	Decrease in coal power over 8-year period	Percentage point difference
World	2022–2030	36% → 4%	32 ↓

Source: Jaeger (2023a).

Mitigation measures and potentials

The emission reduction potential for the electricity sector is estimated to be 10.3 $GtCO_2e$/year (7.4–11.8 $GtCO_2e$/year) for 2030 and 13.0 $GtCO_2e$/year (11.9–14.1 $GtCO_2e$/year) for 2035 at costs less than 200 US$/$tCO_2e$. The primary contributions to these potentials are from increased electricity generation with solar PV and wind energy (table 2). For fossil fuel production, the methane emission reduction potential is estimated to be 1.9 $GtCO_2e$/year (1.4–2.4 $GtCO_2e$/year) for 2030 and 1.7 $GtCO_2e$/year (1.3–2.1 $GtCO_2e$/year) for 2035, most at relatively low costs. This is comparable to the emission reduction potentials reported in (Shukla *et al.* eds. 2022). The full deployment of the mitigation potential in the power sector and fossil fuel production would reduce the emissions from the energy sector by 65 per cent in 2030 and 76 per cent in 2035 compared with the current policy baseline projections.

For solar PV, mitigation potential estimates by 2030 and 2035 have drastically risen since the previous report (UNEP 2017)"publisher":"United Nations Environment Programme (UNEP, where the maximum potential for solar PV was estimated at 4–8 terawatts (TW) of installed capacity by 2030. Literature reports potential installed capacities could reach 6–7 TW by 2030 and 9–12 TW by 2035.[4] We find an additional mitigation potential of 4.2 $GtCO_2e$/year in 2030 and 7.9 $GtCO_2e$/year in 2035. Wind energy also provides a promising potential of 4.1 TW installed capacity, corresponding to 7.7 $GtCO_2$ emission reductions in 2035 compared with the baseline.[5] Decarbonization of the electricity supply system is relevant for all regions in the world, except for a few countries that already rely mostly on low-carbon electricity sources. The sum of the potential emission reductions is enough to reduce emissions in the electricity sector to zero in the course of the next decade.

Barriers and enablers for implementation

The combination of all sources in real-life power systems is not always technically possible and integration takes time. Part of the electricity mitigation potential will be needed to compensate for additional electricity demand from increased electrification in different sectors (e.g. heat pumps, electric vehicles and industrial electrification). On the other hand, there is potential for limiting the growth of electricity use, for example through the use of more efficient electric appliances (see section 6.2.6).

The effective deployment of solar and wind energy technologies is also often constrained by the limitations of existing grid infrastructure, a challenge that is already being felt in much of Europe, the United States of America and China. The current grid systems require significant upgrades to accommodate the variability and distributed nature of renewable energy sources, requiring. substantial investments in modernizing and expanding grid infrastructure (IEA 2023a). In addition, for a smooth integration of solar and wind energy, the use of demand response (e.g. controlled charging of vehicles) and storage systems are essential (Brown *et al.* 2018). Another barrier for the deployment of solar and wind energy is formed by high upfront costs. These can be countered by the use of feed-in tariffs or renewable energy auctions (REN21 2022, p. 85). Also, some regions are very much dependent on employment in coal mining, requiring alternative employment options, for instance in renewable energy manufacturing (IEA 2024c).

The power sector faces the largest investment gap from current levels in the transition to a low-carbon future, with US$2 trillion to 2.9 trillion per year needed by 2035 (Strinati *et al.* 2024). Most of this will fund renewable energy expansion, with additional, significant investments needed for power infrastructure, including grids and energy storage. EMDEs outside China, particularly in the Middle East and Africa, will require steep increases in power sector investment to meet the rapidly growing energy demand driven by low per capita energy consumption and fast economic and population growth.

6.2.3 Industry sector

Sectoral transformation and benchmarks

Transforming the global industry sector will depend on lowering consumption through demand reduction, material efficiency and increased circularity (especially metals recycling); using advanced cementitious material substitution; improving energy efficiency across industrial processes; electrifying industrial processes that currently rely on low- and medium-temperature heat; developing new processes based on solutions like green hydrogen that cannot be easily electrified; and deploying carbon capture, utilization and storage for those emissions that cannot be abated (Bashmakov *et al.* 2022; Fazekas, Bataille and Vogt-Schilb 2022; Shukla *et al.* eds. 2022; Boehm *et al.* 2023). As displayed in table 6.1 and further detailed in appendix E, several sources provide 1.5°C-aligned benchmarks for 2030 and 2035 which quantify the speed and order of magnitude of change required across the global industry sector and which may be useful for informing countries' NDC preparation.

4 Several studies suggest that higher solar PV and wind potentials could be achieved for 2035 (17–22 TW and 10–13 TW, respectively) and 2040 with extensive electrification of the energy system (Jacobson *et al.* 2019; Breyer *et al.* 2020; Bogdanov *et al.* 2021).

5 This figure has a high level of uncertainty, with a range between 5.7 and 13.0 $GtCO_2e$ (Teske ed. 2019; Bogdanov *et al.* 2021; Det Norske Veritas 2023; IEA 2023a).

With emissions from the global industry sector expected to rise, progress towards the 2030 and 2035 benchmarks outlined in this report must rapidly increase to get on track. For some indicators, such as the share of electricity in the industry sector's final energy demand, such progress will require rapid acceleration of current trends in the right direction (Boehm *et al.* 2023). For others, such as the carbon intensity of global cement and steel production, trends are worsening year-on-year and require reversing course entirely (Boehm *et al.* 2023).

Mitigation measures and potentials

Based on updated values from AR6 (Babiker *et al.* 2022), industry as a whole has the potential to mitigate 4.4 $GtCO_2e$/year (4.2–4.8 $GtCO_2e$/year) in 2030 and 6.6 $GtCO_2e$/year (2.4–7.2 $GtCO_2e$/year) in 2035 globally. Achieving the full potential would reduce emissions by 31 per cent in 2030 and 45 per cent in 2035 compared with current policies projections. Mitigation measures include material efficiency (1.2 $GtCO_2e$/year in 2035), enhanced energy efficiency (1.1 Gt $GtCO_2e$/year in 2035), enhanced recycling (1.0 $GtCO_2e$/year in 2035), cementitious material substitution (0.4 Gt $GtCO_2e$/year in 2035), and electrification and fuel switching that is viable but uncompetitive due to regional relative fossil fuel and electricity costs e.g. electric boilers and industrial heat pumps (2.1 $GtCO_2e$/year in 2035). For other options, such as CCS (0.1 and 0.5 $GtCO_2e$/year in 2030 and 2035) and process transformations allowing energy input switching to low GHG electricity and hydrogen (0.7 and 1.2 $GtCO_2e$/year in 2030 and 2035), more potential becomes available moving from 2030 to 2035. This is because more time is available to initiate, design, permit, finance and construct new industrial facilities, which typically take 5–10 years depending on the region. The estimates of emission reduction potential provided are based on known sectoral GHG intensities and forecasted output for iron and steel, cement and concrete, chemicals, non-ferrous metals, and pulp and paper, which are then adjusted by sector using the above mitigation strategies sequentially and additively to avoid double counting (see UNEP-CCC and Common Futures 2024 for detailed methodology and references). Finally, nitrous oxide emissions from nitric acid and adipic acid production can be reduced to a large extent (United States of America, Environmental Protection Agency 2019). Emission reduction for fluorinated gases is addressed in section 6.2.7.

Because industrial facilities last decades, and new facilities take 5–10 years to plan, permit, finance and build, much of the above mitigation measures will take time to mature, beyond 2030–2035. In the short to medium term, i.e. out to 2030 and 2035, material and energy efficiency, enhanced recycling (especially of metals), and cementitious material substitution are all relatively low-cost actions with high impact that do not lock in emissions over the long term, while reducing the need for high-cost production decarbonizaton options (IEA 2019; Bataille 2020; Habert *et al.* 2020; Bashmakov *et al.* 2022; Fennell *et al.* 2022). All the above options, by reducing and replacing fossil fuel use, have strong local air quality improvement impacts (Cheng *et al.* 2023; Wang *et al.* 2024).

Barriers and enablers for implementation

Since the Paris Agreement, knowledge of decarbonization options has evolved quickly in the industry sector. Prior to 2016, most mitigation potential was focused on energy efficiency, some minor electrification and the assumption that broad post-combustion CCS would someday prove viable.

However, other than in a few jurisdictions such as under the European Union Emissions Trading System and a few subnational jurisdictions, almost nowhere in the world is policy strong enough to drive transformational demand and supply-side deep mitigation in the industrial sector (Bataille *et al.* 2024). To activate the potential for material efficiency and circularity/recycling, building codes, public procurement and regulation should all be employed, with education for architects, structural engineers and designers of all kinds. To activate viable electrification, fuel switching and concentrated CO_2 flow CCS options, rising carbon pricing or performance regulations are required (Bashmakov *et al.* 2022). To bring new electrification, hydrogen, process change and post-combustion CCS to market, strong innovation and commercialization support is required, followed by public and private lead markets paying a premium; carbon pricing and regulations alone will not be enough (Bataille *et al.* 2024). To meet mitigation goals, the industrial sector will require between US$0.9 trillion and US$1.2 trillion annually by 2035 (Strinati *et al.* 2024). Key investment areas include carbon capture, electrification of industrial processes, energy efficiency and recycling.

6.2.4 Agriculture, forestry and other land-use sector

Sectoral transformation and benchmarks

Producing enough food to nourish a growing population, while also supporting socioeconomic development, using less land and water, conserving biodiversity and mitigating GHG emissions will require a deep system transformation of the land sector (Schneider *et al.* 2023)health and sustainability goals. Five themes are considered: (1. This will entail fundamental changes in land-use planning, ecosystem management and the production, consumption and disposal of food, fibre and other agriculture commodities like bioenergy crops (Masson-Delmotte *et al.* 2019). Table 6.1 and appendix E outline near-term, 1.5°C-compatible benchmarks for advancing these transformational changes.

Recent historical data suggest that global efforts to achieve land-sector benchmarks for 2030 are off track (Boehm *et al.* 2023). While the GHG emissions intensity of agricultural production has declined slowly but steadily, crop yields have remained relatively flat in recent years, and this means that gains need to accelerate more than tenfold this decade. Demand-side shifts also have yet to occur at a pace commensurate with the crises at hand, for example, with recent trends in food loss heading in the wrong direction. And though the world has seen some progress on reforestation, deforestation remains high (Boehm *et al.* 2023). Still, some countries have made remarkable advances in recent years. Between 2022 and 2023, for example, Brazil and Colombia saw a 26 per cent and 44 per cent decline in permanent forest loss, respectively.[6] Such successes illustrate that rapid change across the land sector is possible.

Mitigation measures and potentials

The land sector has the potential to mitigate approximately 8.0 $GtCO_2e$/year (4.1–16.7 $GtCO_2e$/year) and 12.8 $GtCO_2e$/year (6.3–19.1 $GtCO_2e$/year) in 2030 and 2035, respectively, up to US$200/$tCO_2e$ (table 6.2; appendix E). If the full potential is achieved, the land sector could shift from a source to a sizeable carbon sink by 2035, reducing emissions by 84 per cent in 2030 and 134 per cent by 2035 compared to the current policy projections. Most of the land sector potential come from land-use measures (65 per cent), and the remaining are provided by agriculture measures (16 per cent), and demand-side measures (19 per cent) (table 6.2). The AFOLU sector offers significant near-term mitigation, with most actions readily deployable within the next five years at a relatively low cost (Nabuurs *et al.* 2022). More than half of the potential from forestry is available under US$50/$tCO_2e$.

Land-use measures in this report include reduced deforestation (2.6 $GtCO_2e$/year in 2035), afforestation/reforestation (3.6 $GtCO_2e$/year), and improved forest management (2.2 $GtCO_2e$/year). Coastal wetlands, peatlands, grasslands and other non-forest ecosystems were excluded due to a lack of updated economic data. Current policies already produce a large reduction of deforestation emissions in the baseline, therefore reducing deforestation potential. Reducing deforestation and wetland conversion, particularly of old-growth or primary ecosystems, provide the highest mitigation density (mitigation per unit area) of any AFOLU measure (Roe *et al.* 2021) and can also deliver significant co-benefits, as intact ecosystems continue to sequester carbon and provide vital ecosystem services including the regulation and filtration of water and air, and protection of biodiversity (Nabuurs *et al.* 2022). Regionally, potential for reduced deforestation and afforestation/reforestation is highest in tropical forest countries in Latin America, Southeast Asia and Africa, while improved forest management is more geographically dispersed. Agriculture measures in this report include reducing the methane and nitrous oxide emissions (0.5 $GtCO_2e$/year in 2035) from rice cultivation, nutrient management, enteric fermentation and manure management as well as enhancing carbon removals (1.5 $GtCO_2e$/year in 2035) from soil carbon management, agroforestry and biochar. Broader categories like climate-smart agriculture or regenerative agriculture are excluded due to a lack of updated economic data for 2035. Regionally, mitigation potentials of non-CO_2 emissions and carbon removals in agriculture are highest in the Asia-Pacific region followed by developed countries. Most measures can provide a wide array of potential co-benefits including enhancing soil quality, water efficiency and yields, and reducing pollution (Nabuurs *et al.* 2022). Although agricultural measures have lower mitigation density than measures in forests and other ecosystems, multiple agricultural measures can often be applied on the same parcel of land (Roe *et al.* 2021).

Demand-side measures, including shifting to healthy sustainable diets and reducing food waste, also provide significant potential at 2.4 $GtCO_2e$/year in 2035 when only considering diverted food production and excluding land-use impacts. This potential increases threefold when also accounting for emission reductions from land-use impacts like deforestation. Similar to the agriculture potentials, the highest demand-side potentials are primarily in the Asia-Pacific followed by developed countries.

Barriers and enablers for implementation

Key barriers to implementing land-based mitigation include insufficient institutional support and investment, harmful agriculture subsidies, lack of access to alternative sources of income for farmers and landholders, differences in cultural values, land competition, illegality, weak governance, insecure land ownership and technical capacity (Nabuurs *et al.* 2022). Realizing land-sector potentials will require additional and effective policy support and finance, including for technology transfer, improved governance, land-use planning, tenure rights and community forestry, biodiversity conservation, corporate supply chain management, redirecting perverse subsidies, and payment for ecosystem services (Nabuurs *et al.* 2022).

AFOLU investments face a significant funding gap, with US$1.2 trillion to US$1.4 trillion annually required by 2035 to tackle the interconnected challenges of climate change and the biodiversity crisis (Strinati *et al.* 2024). Currently, most funding originates from and benefits developed economies, while EMDEs outside China, particularly in East Asia, Latin America and Africa, hold 90 per cent of the global potential for nature conservation and 80 per cent for regenerative agriculture (Turner *et al.* 2021; Ishii *et al.* 2023).

6 Deforestation rates were calculated following methods in Boehm *et al.* (2023) and using data available on the Global Forest Watch. Data from Hansen *et al.* (2013), Curtis *et al.* (2018) and Tyukavina *et al.* (2022) are updated to 2023.

6.2.5 Transportation sector

Sectoral transformation and benchmarks

Transforming the global transportation sector to achieve climate goals will require several interconnected shifts (Fazekas, Bataille and Vogt-Schilb 2022; Boehm *et al.* 2023). First, urban planning to bring work, services and goods closer to where people live can reduce demand for some motorized travel altogether. For transport that cannot be avoided, strategies to shift vehicle travel to shared, collective or active transport modes like cycling, walking and public transportation will be paramount. Simultaneously, in 1.5°C-aligned scenarios, electric vehicles replace the internal combustion engine in cars, buses and trucks which are still required on the road, while new zero-emissions fuels are scaled up to decarbonize shipping and aviation transport that cannot be electrified. NDCs represent an important avenue through which countries can communicate plans to contribute to these needed global shifts. As shown in table 6.1, several sources analyse how quickly the global transportation system transforms to meet 1.5°C-aligned benchmarks.

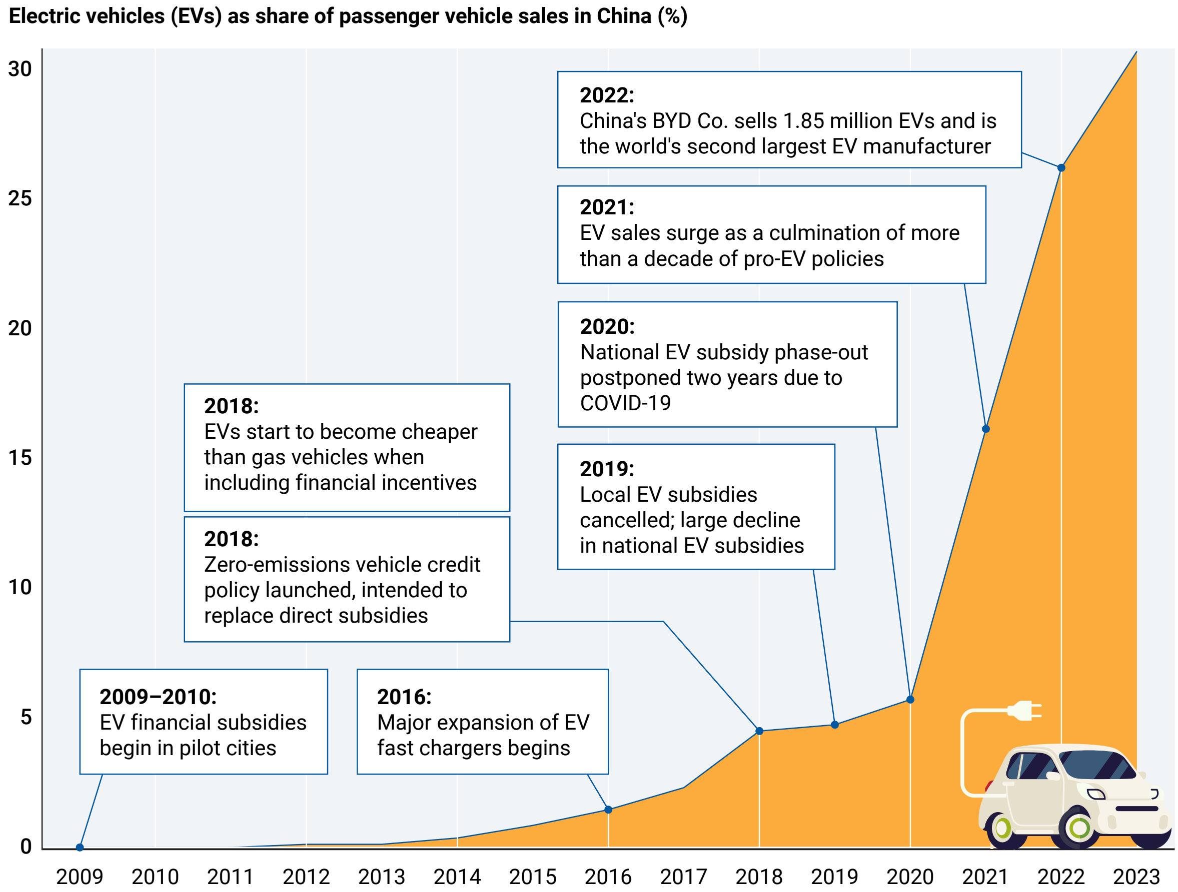
Progress in accelerating these needed transformations across the global transport sector is uneven. For instance, one recent assessment found that shifts to more sustainable modes of transport and decarbonization of longer-haul transit modes like trucking, shipping and aviation are not moving fast enough, and, in some cases, are heading entirely in the wrong direction (Boehm *et al.* 2023). However, the same report found that efforts to electrify common modes of road transport are moving at more promising rates towards needed future benchmarks (Boehm *et al.* 2023). Indeed, the share of electric vehicles in light-duty vehicle sales is already on track to achieve a 1.5°C-aligned 2030 benchmark (Boehm *et al.* 2023), with such global progress made possible by significant advances within a handful of key countries (box 6.2).

Box 6.2 Spotlight on national efforts to scale up electric vehicle sales

Across the world, electric light-duty vehicle sales have been growing exponentially year on year in large part because of technological improvements and falling costs resulting from government support (Boehm *et al.* 2023; Jaeger 2023c; IEA 2024a). Much of this rapid change can be attributed to the leading countries that have prioritized the rapid scale-up of electric vehicle sales in their national policy agendas (Jaeger 2023c). For example, in Norway all-electric vehicles constituted 93 per cent of light-duty car sales in 2023, followed by Iceland (74 per cent), Sweden (60 per cent), Finland (54 per cent), Belgium (41 per cent) and China (38 per cent) (IEA 2024a).

Because of the scale of its economy, China is the world's biggest player when it comes to electric vehicle sales, having sold more in 2023 than the rest of the world combined (Jaeger 2023c; IEA 2024a). These sales have been achieved after more than a decade of supportive policy (figure B6.3) aimed to provide the country with a competitive edge in electric automobile manufacturing, as well as to reduce air pollution and dependence on imported oil (Jaeger 2023c). Major policy developments elsewhere, such as the United States of America Inflation Reduction Act and European Union Green Deal, are helping incentivize the continued uptake of electric vehicles, although progress in the United States of America will require overcoming opposition to the transition. These successes will need to be expanded to others, especially in those countries lacking charging infrastructure and renewable energy, which can be spurred with supportive policies and investments.

Figure B6.3 Policy interventions in China have led to increases in electric vehicles as share of passenger vehicle sales



Note: Electric vehicles include all-electric vehicles, not plug-in hybrid electric vehicles.

Source: Jaeger (2023c); IEA (2024b).

Mitigation measures and potentials

The emission reduction potential for the transport sector is estimated to be 3.2 $GtCO_2e$/year (1.6–4.8 $GtCO_2e$/year) for 2030 and 4.8 $GtCO_2e$/year (2.4–7.2 $GtCO_2e$/year) for 2035. The primary contributor to emission reductions is road transport, with an estimated reduction potential of 2.5 and 3.6 $GtCO_2e$/year in 2030 and 2035, respectively. Other contributions come from shipping and aviation. Achieving the full mitigation potential would reduce emissions by 36 per cent in 2030 and 53 per cent in 2035 compared with the current policies projections (for an overview, see table 6.2 and table E.3 in appendix E). More detailed information on sources, calculations and considerations are provided in UNEP-CCC and Common Futures (2024).

In road transport, important contributors to emission reduction potential are the replacement of gasoline and petrol cars with electric vehicles and the shift to public transport and (e-)bikes. In recent years, the transport sector has seen rapid growth in electric vehicle sales. This increased adoption of electric vehicles is included in the current policy baseline scenario (UNEP-CCC and Common Futures 2024). In its Stated Policies Scenario model, the IEA's recent Global EV Outlook (IEA 2024a) shows an increased contribution of electric vehicles to avoided emissions by 2030 compared with earlier assessments, growing from 0.2 $GtCO_2e$/year in the 2020 Global EV Outlook (IEA 2020) to 0.8 $GtCO_2e$/year in the 2024 Global EV Outlook. However, a further increased uptake of electric vehicles is estimated to have an additional emission reduction potential of 0.4 and 0.9 $GtCO_2e$/year by 2030 and 2035, respectively (IEA 2024a). In addition, a shift to public transport and (e-)bikes can significantly reduce emissions from road transport in urban areas, with an estimated potential of 1.4 $GtCO_2e$/year by 2035 (Institute for Transportation & Development Policy and University of California, Davis 2015).

Shipping is projected to contribute up to 0.2 $GtCO_2e$/year of emission reduction potential in 2030 (Faber, van Seters and Scholten 2023) and up to 0.4 $GtCO_2e$ by 2035 (IEA 2023b), specifically from energy efficiency, operational optimization and a shift to zero- and low-emission fuels like biofuels, hydrogen, methanol and ammonia.

Aviation can reduce emissions by up to 0.5 $GtCO_2e$/year by 2030 and 0.8 $GtCO_2e$/year by 2035 compared with the baseline scenario (Bergero *et al.* 2023; IEA 2023b) respectively, of projected business-as-usual aviation emissions in 2050. However, further reductions will depend on replacing fossil jet fuel with large quantities of net-zero emissions biofuels or synthetic fuels (that is, 2.5–19.8 EJ of sustainable aviation fuels, mainly through limiting the increase in demand for aviation, a shift to alternative fuels and improvements in operations and aircraft technology.

Barriers and enablers for implementation

Materializing the identified options for mitigating transport emissions faces a variety of challenges, including technological dependencies, regulatory changes, social and cultural factors, and shortfall of significant investments (Geels *et al.* 2017). For example, promoting car-free mobility and reduced aviation requires changes in individual behaviour and societal acceptance (often slow to happen), an increase in electric vehicles and high-speed railways requires urban planning changes and significant infrastructure investments, and developing sustainable fuels for aviation and shipping demands both international coordination and investment in research and devlopment (Sclar *et al.* 2019; Borén 2020; Marinaro *et al.* 2020; Shukla *et al.* eds. 2022). Addressing these barriers depends on a comprehensive and coordinated effort from policymakers, industry stakeholders and communities. The transport sector will need between US$1.1 trillion and US$3.6 trillion per year by 2035 (Strinati *et al.* 2024). A significant portion of this investment will be directed towards low-emission vehicles, particularly electric vehicles and the infrastructure needed to support them, such as chargers.

6.2.6 Buildings sector

Sectoral transformation and benchmarks

To align the global buildings sector with the Paris Agreement, major shifts include improving the energy efficiency within buildings, decarbonizing the remaining energy used for heating, cooling and appliances, retrofitting the existing building stock and ensuring that new buildings are constructed to be zero-carbon in operation (Fazekas, Bataille and Vogt-Schilb 2022; Boehm *et al.* 2023). NDCs containing sectoral targets to promote each of these shifts will be critical. Table 6.1 illustrates the speed with which the buildings sector should be transformed according to multiple studies that have derived 1.5°C-aligned global benchmarks.

Publicly available data, however, indicate that recent progress made in unlocking these much-needed shifts remains well off track from the speed and scale required (Boehm *et al.* 2023). Supporting enabling policy which incentivizes the shifts needed to decarbonize buildings will be critical for enabling the achievement of 1.5°C-aligned global benchmarks for the buildings sector.

Mitigation measures and potentials

The mitigation potential estimates in the built environment are based on the AR6 (Cabeza *et al.* 2022), interpolating 2035 numbers from 2030 and 2040 estimates, due to a lack of new available data. This results in a total mitigation potential for the buildings sector of 3.2 $GtCO_2e$/year (2.4–4.0 $GtCO_2e$/year) for 2030 and 4.2 $GtCO_2e$/year (2.1–5.2 $GtCO_2e$/year) for 2035, with direct emission reductions contributing 1.1 $GtCO_2e$/year and 1.2 $GtCO_2e$/year, respectively. An overview of the potentials by abatement measure is presented in table 6.2 and table E.3 in appendix E.

Up to 0.6 and 0.7 $GtCO_2e$/year of the emission reduction potential in 2030 and 2035, respectively, is in developed countries, primarily through avoided demand and efficiency improvements for new builds. In developing countries, 0.5 $GtCO_2e$/year by 2030 and 0.6 $GtCO_2e$/year by 2035 of the emission reduction potential are from heating, ventilation and air conditioning systems, demand-side management measures for new buildings and improved efficiency of appliances. For appliances, UNEP (2023) and IEA (2024b) suggest the potential could be up to double what is reported in table 6.2 of this chapter, but due to limitations of these data, such potential was excluded from the assessment.

Barriers and enablers for implementation

For the buildings sector, many barriers exist, including the long lifetime of buildings, the high costs of building retrofit and split incentives (landlord–tenant dilemma). The major policy for speeding up mitigation in the buildings sector is energy efficiency standards for appliances and new buildings. These have been shown to be successful, and broader application of ambitious standards is the key policy in this sector (Cabeza *et al.* 2022). The main challenge is with the existing building stock, for which a range of policy instruments can be applied. Energy performance standards may also be instrumental here to speed up the low-carbon transition (Kamenders, Stivriņš and Žogla 2022).

The buildings sector will require investments of US$1.3 trillion to US$2.1 trillion per year by 2035 (Strinati *et al.* 2024). Much of this investment will focus on energy efficiency measures in retrofits and new construction, with significant funds also directed towards heating, ventilation and air conditioning systems, water heaters and cooking systems.

6.2.7 Other

In addition to the deep emission cuts in the abovementioned sectors, it will be important to bridge the emissions gap with efforts in other areas, most significantly the waste sector, non-CO_2 gases (e.g. fluorinated gases), and CO_2 removal. While these mitigation opportunities are not treated comprehensively in this chapter, tables 6.1 and 6.2 present relevant benchmarks and sectoral mitigation potentials below US$200/$tCO_2e$. Waste and other emissions accounted for 4 per cent of total emissions in 2023, representing a sizeable opportunity for reducing emissions. Additionally, addressing fluorinated gases, which grew by 4.2 per cent in 2023 (chapter 2), presents another opportunity, with a large part of the emissions regulated under the Kigali Amendment to the Montreal Protocol. Finally, as the Emissions Gap Report 2023 noted and the State of Carbon Dioxide Removal Report further detailed (UNEP-CCC and Common Futures 2024), CO_2 removal is necessary to scale to the gigaton level by mid-century in pathways limiting warming to 1.5°C, and the next set of NDCs should ideally include countries' commitments to ramping up such approaches, as relevant.

6.3 Substantial increases in investments and finance are required to accelerate action

6.3.1 Overview of global climate investment needs

To achieve the system transformations described in section 6.2, current investment patterns must shift from high carbon to low carbon and investments in mitigation must be substantially increased. Over the past decade, climate investments, including both mitigation and adaptation, have grown steadily, reaching a record of nearly US$1.3 trillion per year in 2021/2022, of which mitigation accounted for about US$1.2 trillion (Buchner *et al.* 2023).

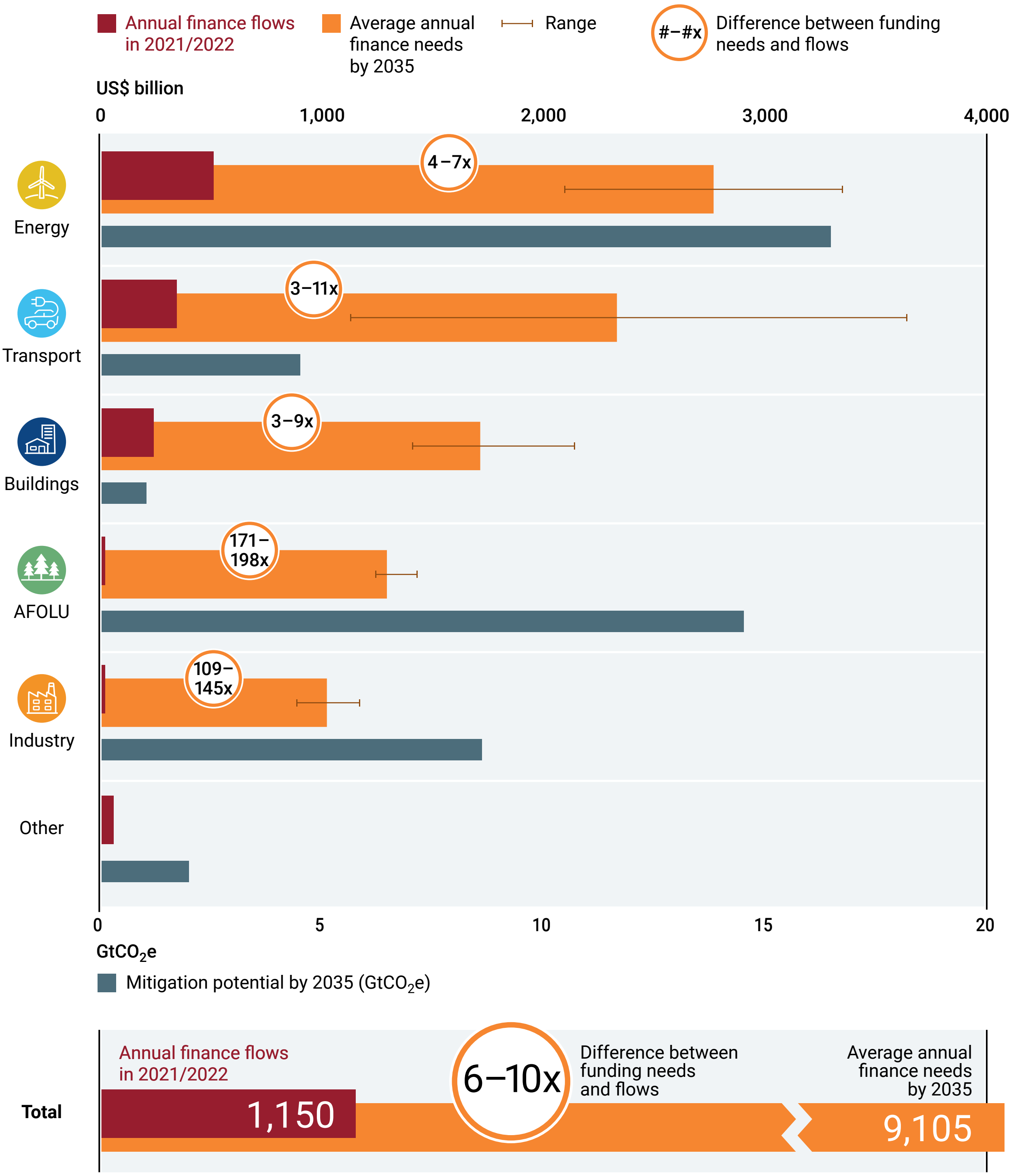
Available studies of the investments needed for a net-zero pathway indicate that, overall, annual investments need to increase at least sixfold from current levels to reach US$6.7 trillion to US$11.7 trillion by 2035 (an average of US$9.1 trillion) (The Food and Land Use Coalition 2019; Deutz *et al.* 2020; Stern 2021; BloombergNEF 2022; Krishnan *et al.* 2022; Lubis, Young and Doherty 2022; Shukla *et al.* eds. 2022; UNEP 2022; IEA 2023b; IRENA 2023; Thornton *et al.* 2023; Strinati *et al.* 2024).[7]

While these figures may seem daunting, only a small share of the estimated investments will be additional, since considerable investments will be needed each year to meet development needs, including the growing demand for energy, especially in EMDEs outside China. The estimated global incremental mitigation investment for a net-zero transition scenario is US$0.9 trillion to US$2.1 trillion per year between 2021 and 2050 (Krishnan *et al.* 2022; Energy Transitions Commission 2023; IRENA 2023), which is substantial but manageable in the broader context of the near US$110 trillion global economy and financial markets (International Monetary Fund 2024). In 2023 and 2024, the global economy – measured by GDP – grew by US$5 trillion year on year (International Monetary Fund 2024), and in 2022 alone, global fossil fuel subsidies (both explicit and implicit) reached US$7 trillion (Black *et al.* 2023). Similarly, between US$1.3 and $6 trillion per year in global subsidies (both explicit and implicit) are allocated to agriculture and fisheries, supporting actions that contribute to land degradation, deforestation and the depletion of fish stocks (Damania *et al.* 2023). These figures highlight the potential to address climate, environment and development goals by shifting investment patterns.

7 The Climate Policy Initiative (CPI) compiles and standardizes data on climate investment needs from a wide variety of sources to provide a comprehensive overview of the size of the gap to date. To reflect the variability across different scenarios considered, needs estimates in this report are presented as ranges of investment needed.

As shown in figure 6.2, which also includes the sectoral mitigation potentials presented in section 6.2, mitigation investment needs and current flows vary across key sectors, with a considerable increase in investment required to meet the needs in AFOLU and industry in particular, relative to current levels.

Figure 6.2 **Annual climate investment flows in key mitigation sectors, annual investment needs to reach a 1.5°C trajectory and mitigation potential in 2035**



Source: Adjusted from the Climate Policy Initiative (Buchner *et al.* 2023). Average annual finance needs come from CPI (Strinati *et al.* 2024) and are based on the collection and standardization of needs estimations from BloombergNEF (2022; Lubis, Young and Doherty 2022), The Food and Land Use Coalition (2019), IEA (2023b), IPCC (Shukla *et al.* eds. 2022), IRENA (2023), Stern (2021), McKinsey (Krishnan *et al.* 2022), Deutz *et al.* (2020), Thornton *et al.* (2023) and UNEP (2022).

6.3.2 Investment needs in EMDEs outside China

A considerable increase in mitigation investments will be needed particularly in EMDEs outside China. Investment growth in these countries has slowed since the 2008 global financial crisis, with annual growth rates dropping from 6 per cent in the 2000s to just 3 per cent in the 2010s (World Bank 2024). In EMDEs outside China, the need for climate investment is closely tied to broader development challenges and needs. These regions are already struggling with public health, human capital, food and energy security, rising debt and political tensions, all of which are exacerbated by climate change. In addition, these countries also face an urgent need for infrastructure and human capital investments as a result of rapid demographic growth, urbanization and economic transformations. With the global population expected to grow by 1.9 billion people by 2050 – with all this growth concentrated in EMDEs outside China (Department of Economic and Social Affairs 2024) – a rapid and sustained increase in investment is essential to support sustainable development and ensure long-term growth in these countries.

Low-carbon investments in EMDEs are therefore not just a mitigation strategy. First and foremost they are a development strategy that delivers significant benefits such as low and predictable energy costs, increased access to energy, improved sanitation, enhanced food security and more resilient economies.

Mitigation solutions in EMDEs continue to be underfunded, receiving only 13.5 per cent of global mitigation investment in 2021/2022, or about US$156 billion per year (Buchner *et al.* 2023). Of this, only 10 per cent reached the least developed countries. It is estimated that an eight- to sixteenfold increase in mitigation investment will be needed in EMDEs outside China by 2030 to support sustainable development and growth and achieve climate goals (IEA 2023c; Songwe, Stern and Bhattacharya 2022). Funding will need to be more equally distributed across regions, with significant capital mobilization required, for example in Sub-Saharan Africa (currently receiving only 9 per cent of total mitigation investments to EMDEs outside China). Improved sectoral distribution of mitigation investments in EMDEs outside China will also be needed. While expanding renewable energy is critical for meeting growing development needs without raising emissions, attention must also be given to other key sectors, particularly AFOLU, given the mutually reinforcing impacts of the climate and biodiversity crises.

Low-carbon investments require significant upfront capital but promise substantial long-term savings and benefits. Shifting away from high-carbon activities will not only cut fossil fuel-related costs (including savings on fuel costs and import bills, redirected investments in fossil fuel infrastructure, reduced operating and maintenance costs, and the elimination of fossil fuel subsidies) but also deliver wide-ranging economic, health and social benefits, including lower health-care expenses resulting from improved air quality and a healthier, more productive workforce (Black *et al.* 2023). Conversely, failing to align investments with the 1.5°C goal could result in severe economic consequences, such as stranded assets and significant economic and social losses (Bilal and Känzig 2024; Black *et al.* 2022; Semieniuk *et al.* 2022).

Challenges such as unclear policy frameworks, financially strained utilities, high cost of capital and low institutional capacities must be addressed to unlock the necessary investments in these regions.

Further, how these investments are implemented will have a lasting impact on climate and development outcomes, as section 6.2 also illustrates. Poorly planned infrastructure could lock in high-carbon activities for decades, undermining development prospects and worsening climate risks. Therefore, much of the investment required for climate action overlaps with that needed for sustainable development, making these investments mutually reinforcing and essential for a prosperous, climate-resilient future.

6.3.3 Financing climate-related investments

The balance between private and public finance will differ across regions, reflecting their unique economic structures and development stages. In advanced economies, the private sector is expected to continue to dominate financing, while in China, a more balanced distribution between private and public sources can be expected. In contrast, EMDEs outside China will likely continue to rely more heavily on public financing (Bhattacharya *et al.* 2023; Songwe, Stern and Bhattacharya 2022). The mix of financing will also vary by investment type, with the private sector likely to take the lead in commercially viable technologies and the public sector focusing on strategic areas that require significant upfront capital or carry higher risks.

In advanced economies and China, the focus will be on creating incentives to shift investments from high- to low-carbon industries. The primary challenge lies in scaling up finance from both domestic and international sources in EMDEs outside China to boost mitigation investments, which currently remain at low levels. This will require concerted efforts across all capital pools, with a particular focus on catalysing private and domestic finance, and the mobilization of resources across four key areas (Songwe, Stern and Bhattacharya 2022):

- **Domestic resource mobilization**, encompassing both public and private domestic sources, will be foundational in EMDEs outside China. Domestic sources are expected to provide the majority of the required financing in these regions. Effective domestic resource mobilization will involve improving tax collection, phasing out harmful subsidies and enhancing the efficiency of public spending.

- **Private sector finance.** The private sector will be the largest source of external finance in EMDEs outside China, particularly in driving the energy transition and supporting other climate-related investments. However, higher interest rates, unclear policy frameworks and market design, and a high cost of capital have meant that private finance is often either unavailable or available only at a high cost for green investments in these regions (IEA 2023d). Although renewable energy sources such as solar and wind have become increasingly cost-competitive with coal and gas, the high cost of capital for projects in EMDEs outside China – often compared with most advanced economies – undermines their competitiveness against fossil fuel-based energy, despite the rapid decline in technology costs (Buchner *et al.* 2023; UNEP 2023). The mobilization of private capital at scale will require robust public sector support in terms of policy frameworks, risk mitigation and creating conducive investment environments.

- **Multilateral development banks** have a catalytic role to play in mobilizing private capital. Ongoing reforms aim to enhance their ability to reduce, manage and share risks, thereby lowering the cost of capital and supporting critical public sector programmes (G20 Independent Experts Group 2023a; G20 Independent Experts Group 2023b). Multilateral development banks can enhance private sector confidence through grants, concessional finance, and credit and risk guarantees. By leveraging their resources, multilateral development banks can facilitate capacity development and innovation, making high-risk markets more attractive to private investors.

- **Concessional finance**, although limited, will be crucial for investments in public goods that do not generate revenues or savings for businesses, including some areas of nature conservation and the just transition. Concessional funds are also essential for leveraging additional finance from other sources and de-risking investments to attract private capital.

Making these investments happen is complex. It requires countries to have the capacity to make informed investment decisions as well as to translate those decisions into tangible programmes and project pipelines. This demands robust policy and institutional frameworks that foster the right enabling environment, with a strong emphasis on climate action and broader sustainability goals (Bhattacharya *et al.* 2022).

However, scaling up climate investments in EMDEs will remain theoretical unless debt challenges and fiscal constraints, particularly in poorer and more vulnerable countries, are addressed. The financial strain caused by the COVID-19 pandemic, rising fuel and food costs due to global conflicts, inflation and increased debt servicing has compounded these challenges (Chuku *et al.* 2023).

Beyond increasing and utilizing all sources of finance more effectively, there is a pressing need to tackle the shortfalls in the quality of finance provided. Finance can become more affordable, transparent, accountable, predictable, accessible and more focused on supporting poor and vulnerable countries.

6.3.4 Raising national ambition in the next round of NDCs

The next NDCs must meet the immense financial and strategic demands of global climate action if they are to align with the Paris Agreement's temperature goal. To achieve this, NDCs must be more ambitious, actionable and inclusive.

The annual financial needs outlined in the latest NDCs of developing countries are projected to range between US$455 billion and US$584 billion per year by 2030 (United Nations Framework Convention on Climate Change Standing Committee on Finance 2024). As countries prepare and submit their enhanced NDCs, there is an opportunity – particularly for EMDEs outside China – to raise their ambition and provide more detailed information on their needs for means of implementation, including financing needs, as well as to develop robust transition investment plans in these documents.

Enhanced NDCs offer a critical opportunity for these countries to send clear policy signals that can attract private investment. Effective country leadership is vital to foster collaboration with the private sector, development finance institutions and international partners. This collaboration should revolve around well-defined investment strategies and sector-specific platforms that create a robust climate for sustainable investment.

Key elements that should define "good" NDCs in the future focus on enhancing investment, scaling up finance, ensuring a just transition and addressing structural barriers.

Key elements of enhancing investments in the next round of NDCs

1. Including comprehensive investment plans

Critical sectors such as power, industry, transport, buildings and AFOLU require significant investment increases to meet climate goals. To attract and mobilize these investments, countries must ensure that their NDCs include comprehensive investment plans setting out the investment required in each sector. This involves not only a thorough scoping, scheduling, costing, projecting of returns on investment and risk profiling of each mitigation measure but also creating a well-defined project pipeline. Having a robust project pipeline as part of the investment plans will be crucial in attracting private capital, as it provides potential investors with clear, actionable opportunities rather than abstract targets. By presenting detailed, viable projects, countries can more effectively engage both public and private investors, ensuring that the necessary funds are directed where they are most needed.

2. Outlining domestic efforts and external climate finance needs

To fill the current mitigation investment gap, both domestic and international finance sources will be crucial. Per article 9 of the Paris Agreement (United Nations Framework Convention on Climate Change 2016), international support in EMDEs will be key to reaching both climate and development goals. The next round of NDCs offers an opportunity for EMDEs to specify more clearly the portion of investments they expect to mobilize domestically (unconditional NDC) and outline their climate finance needs (conditional NDC) at the sectoral and project level, based on realistic financing scenarios. At the same time, NDC investment plans that demonstrate ambitious domestic efforts – including mobilization of domestic resources, plans to enhance the policy and regulatory environments, measures to improve conditions for private investments – will signal national commitment and boost confidence among private and international investors (public and private).

3. Ensuring a just transition

As countries shift to low-carbon economies, it is crucial that this transition is equitable and supports affected communities. NDCs should include comprehensive investment strategies for a just transition, such as workforce retraining, community engagement and support for marginalized and vulnerable groups, including women and Indigenous communities. By ensuring these groups have a voice in decision-making processes and by implementing support schemes for sectors most affected by the transition, countries can enhance social acceptance and ensure that the benefits of climate action are broadly shared. This approach not only facilitates a smoother transition but also contributes to broader development goals.

4. Addressing structural barriers

Structural barriers such as the high cost of capital, unclear policy frameworks and low institutional capacities present significant obstacles to investment flows, particularly in EMDEs. While the next generation of NDCs may not directly resolve all these issues, they can play a critical role in fostering an environment conducive to overcoming these challenges. As part of the NDC process, countries should prioritize the exchange of knowledge and experiences regarding what policies and strategies have proved effective (and which have not) in fostering a stable investment climate. This knowledge transfer can be as vital as the transfer of technology and finance, enabling countries to learn from one another's successes and failures. By sharing best practices and lessons learned, countries can collectively improve policy frameworks, strengthen institutional capacities and create more favourable conditions for attracting investment.

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Chapter 2

B

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