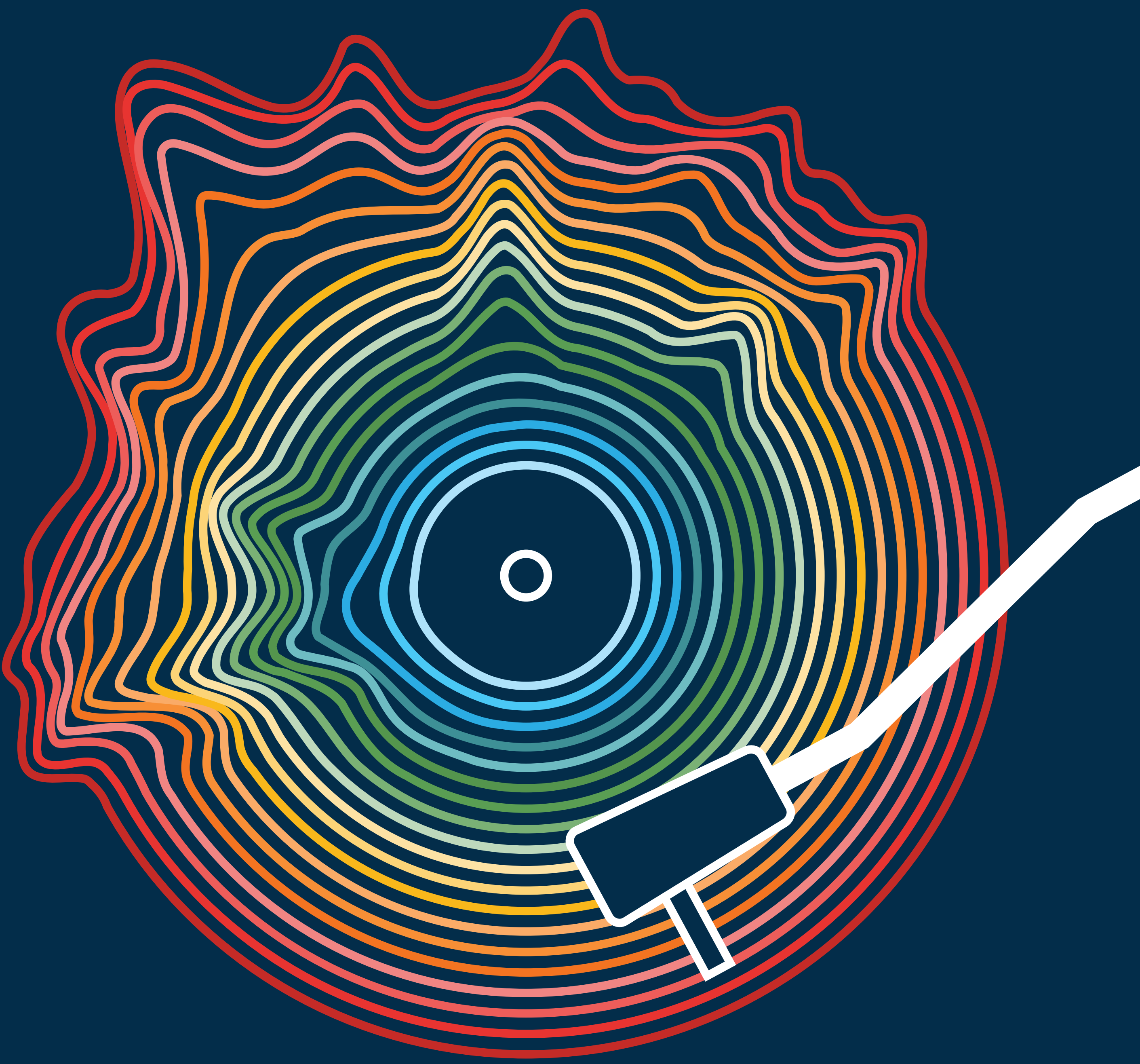
UN environment programme

Broken Record

Temperatures hit new highs, yet world fails to cut emissions (again)

Appendices



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Appendices

Emissions Gap Report 2023

Appendix A

Supplementary material for chapter 2: Global emissions trends

A.1 Data sources for estimating national greenhouse gas emissions

Under the United Nations Framework Convention on Climate Change, countries submit national greenhouse gas (GHG) inventories to inform and track progress towards the goals of the Paris Agreement. However, while Annex I countries submit such inventories each year, non-Annex I countries do not, limiting their use in tracking the latest trends in global and national emissions.

A number of other independent databases exist to fill the need for comprehensive and timely emissions data. These include the Emissions Database for Global Atmospheric Research (EDGAR), Potsdam Real-time Integrated Model for probabilistic Assessment of emissions Paths (PRIMAP), Climate Analysis Indicators Tool (CAIT) and Community Emissions Data System (CEDS).

In chapter 2 of the Emissions Gap Report 2023, EDGAR is used to estimate global and national GHG emissions – excluding carbon dioxide (CO_2) emissions from land use, land-use change and forestry (LULUCF) – as it is the most comprehensive and up-to-date database at the time of publication, with estimates available for the previous year (Crippa *et al.* 2023).

A.2 Comparison of national GHG emissions data

EDGAR emissions data differs from national inventories in years where data is available. Figure A.1 compares the emissions of the G20 group using the EDGAR from chapter 2 versus PRIMAP Hist-CR, a database that prioritizes reported national inventory data, but fills gaps using other available sources (Gütschow and Pflüger 2023). Differences in the latest year of data (2021) are relatively trivial in some cases, such as Japan, South Africa and the United Kingdom, but are more substantial in the cases of Indonesia, the Russian Federation, Saudi Arabia and Türkiye. Further research is required to determine the drivers of differences between data sets, which can result from varying estimation methodologies, system boundaries and primary sources (Minx *et al.* 2021).

Figure A.1 GHG emissions trends of the G20 across data sets

Note: Global warming potentials with a time horizon of 100 years from the Intergovernmental Panel on Climate Change Fourth Assessment Report are used to aggregate GHG emissions. Percentages following each country name refer to the respective difference in emissions between data sets in the last available year (e.g. the estimated emissions for Argentina are 4.1 per cent higher in EDGAR than in PRIMAP HIST-CR).

A.3 GHG emissions of high-income versus low- and middle-income countries

Table A.1 Comparison of emissions metrics for high-income versus low- and middle-income countries

Country grouping	Members of group in the G20	GHG emissions ($GtCO_2e$)		GHG emissions (% of world)		Per capita GHG Emissions (tCO_2e)	
		2000	2021	2000	2021	2000	2021
High-income countries	Australia, Canada, EU27, Japan, Republic of Korea, Saudi Arabia, United Kingdom, United States of America	15.3	14	43	28	14.1	11.5
Low- and middle-income countries	Argentina, Brazil, China, Indonesia, India, Mexico; Russian Federation, Türkiye, South Africa	18.9	34.9	53	69	3.8	5.3

Note: All numbers in table A.1 relate to the high- and low- and middle-income country categories, and not for the G20 members of each of the categories presented in the table. GHG emissions include LULUCF CO_2 (inventory-based). Countries above a threshold of US$13,846 gross national income per capita are classified as high-income countries, while all below this threshold are low- and middle-income countries, following the World Bank (2023) income classification scheme.

References

Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E. *et al.* (2023). *GHG Emissions of All World Countries*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/953322.

Gütschow, J. and Pflüger, M. (2023). The PRIMAP-hist national historical emissions time series (1750–2021) v2.4.2. Zenodo. https://doi.org/10.5281/zenodo.7727475. Accessed 10 November 2023.

Minx, J.C., Lamb, W.F., Andrew, R.M., Canadell, J.G., Crippa, M., Döbbeling, N. *et al.* (2021). A comprehensive and synthetic dataset for global, regional, and national greenhouse gas emissions by sector 1970–2018 with an extension to 2019. *Earth System Science Data* 13(11), 5213-5252. https://doi.org/10.5194/essd-13-5213-2021.

World Bank (2023). World Development Indicators. https://datatopics.worldbank.org/world-development-indicators/. Accessed 6 August 2023.

Appendix B

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

B.1 Progress towards achieving the Cancun Pledges by 2020: An update focusing on G20 members

This section provides an update on the achievement of the Cancun Pledges, with a primary focus on the G20 members. The assessment considers the most recent emissions trends up to 2020 and builds on the analysis in the United Nations Environment Programme (UNEP) 2017 Emissions Gap Report. The emissions estimates of the Cancun Pledges were based on UNEP (2017). Notably, updates were not made for some of the estimates based on the impact of the most recent macroeconomic developments. For example, China and India have greenhouse gas (GHG) intensity targets based on the ratio of GHG emissions to gross domestic product (GDP), which were not updated. Figure B.1 compares the 2020 GHG emissions from official GHG inventories if available, or from independent data sources with the trajectories associated with the achievement of the Cancun Pledges of these members. For the Annex I countries within the G20 economies, the authors relied on official GHG inventories submitted in 2022. These inventories use 100-year global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). However, as of September 2023, official data for the 2020 emissions from the most recent national communications and biennial reports (NC/BR) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) are not available for most of the non-Annex I countries within the G20 economies. Therefore, the authors used the GHG emissions (excluding land use, land-use change and forestry [LULUCF]) data of chapter 2, as based on the Emissions Database for Global Atmospheric Research (EDGAR) (see appendix A.1), supplemented with the GHG data of the Potsdam Real-time Integrated Model for probabilistic Assessment of emissions Paths (PRIMAP) database (Gütschow, Günther and Pflüger 2021). Additionally, LULUCF emissions inventory data from Grassi *et al*. (2022) were incorporated to complete the dataset.

This is further described in box B.1, while the findings are presented in figure B.1 and the sources are described in table B.1.

Box B.1 Assumptions of the assessment of progress towards Cancun Pledges (adjusted based on UNEP 2017)

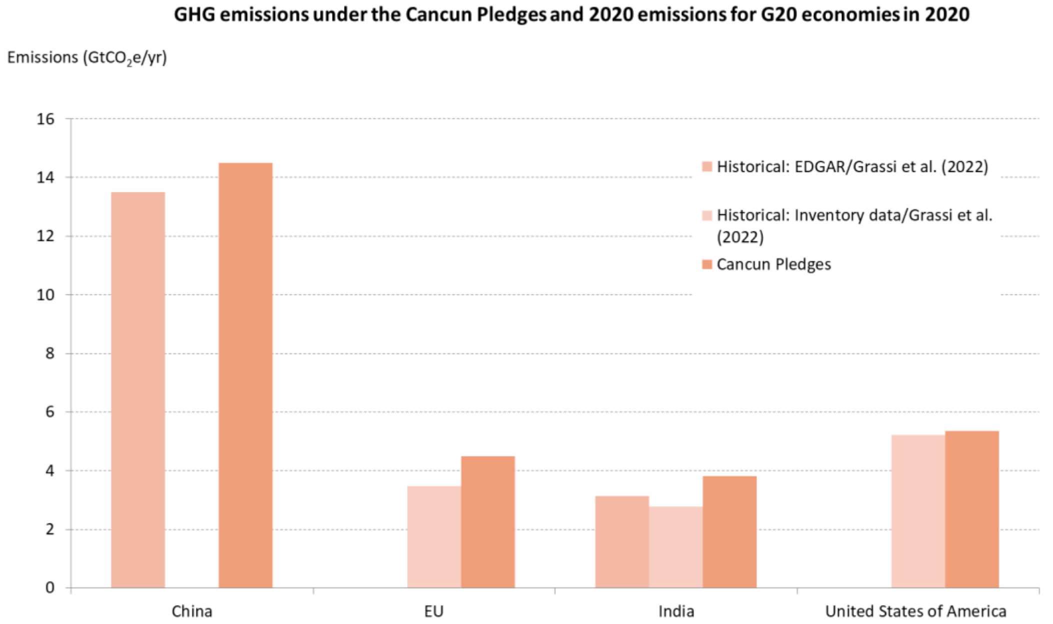
For each G20 member, figure B.1 compares estimates for 2020 emissions under two cases:

1 **Pledge case (official data):** Identifies the maximum level of GHG emissions that each country or Party could emit in 2020 and still meet its pledge, without considering the use of offsets. If a pledge is presented as a range (for Australia, Brazil, China and India in figure B.1), the less ambitious end of the range is adopted as the official pledge estimate. If a country has both a conditional and an unconditional pledge (Indonesia), only the unconditional pledge is used. If a country has only a conditional pledge (Mexico and South Africa), the conditional pledge is used. For countries whose pledges are framed relative to a baseline scenario, it is assumed that baselines are not adjusted in the future. Where available, the 2020 emissions level described by the country or Party as the pledge level is used; alternatively, these levels are calculated working from official base year or baseline data.

2 **2020 GHG emissions** from the official GHG inventories (if available), or from independent data sources. For Annex I countries, the authors used official GHG inventories submitted in 2022; the inventories used 100-year GWP values from AR4.

Projections considering only a limited subset of sectors and gases, for example, carbon dioxide (CO_2) emissions from fossil fuels, are omitted as they cannot be compared to projections and targets that include the full set of GHGs across the entire economy.

Figure B.1 GHG emissions (all gases and sectors, including LULUCF) of G20 members by 2020 under the Cancun Pledges



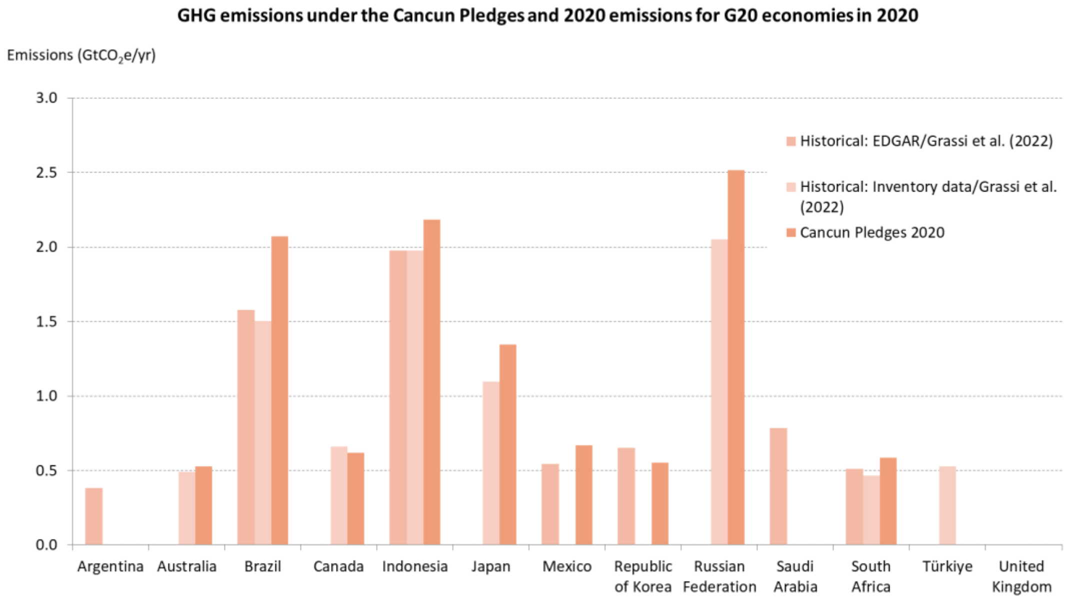


Table B.1 Official and independent sources for emissions data in 2020 and the Cancun Pledges

Country	Has achieved Cancun Pledge? (No: if more than 10%) [a]	2020 emissions: [b] 1. Official inventory data (if available) 2. Independent source	2020 Pledge case [b] Based on official data, UNEP (2017)	Description of Cancun Pledges and 2020 emissions details
Argentina [d]	No pledge	Chapter 2 (UNEP 2023)	No pledge	
Australia [d]	Yes	Official GHG inventory (Australia 2022) [c] 500.9 (for the purpose of Cancun Pledge)[1]	Australia (2022)[2]	Reduce emissions by 5% below 2000 level by 2020, assessed on an emissions budget (2013–2020) according to Kyoto Protocol classifications. This was most recently set out in chapter 3 of Australia's fifth Biennial Report (unconditional).
Brazil [d]	Yes	Chapter 2 (UNEP 2023) Official GHG inventory	Brazil (2010)	Reduce emissions by 36.1–38.9% below business as usual (BaU) by 2020 (unconditional).
Canada [e]	No	Official GHG inventory	Canada (2016)	Reduce emissions by 17% below 2005 level by 2020 (conditional).
China [d]	Yes	Chapter 2 (UNEP 2023) PRIMAP (Gütschow, Günther and Pflüger 2021)	UNEP (2017) based on China (2012)[3]	Lower CO_2 emissions per unit of GDP by 40–45% by 2020 compared to 2005 level. Increase share of non-fossil fuels in primary energy consumption to around 15% by 2020. Increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion m^3 by 2020 from 2005 level.
EU28 [e]	Yes	Official GHG inventory [c]	European Environment Agency (EEA) (2014)	Reduce emissions by 20% below 1990 level by 2020 (unconditional).
India [d]	Yes	Chapter 2 (UNEP 2023) PRIMAP (Gütschow, Günther and Pflüger 2021)	UNEP (2017) based on India, Planning Commission (2011; 2014)	Reduce emission intensity of GDP by 20–25% below 2005 level by 2020. 2020 Pledge case is calculated based on assumed 20% reduction in GHG intensity (India, Planning Commission 2011), the 2020 GDP from India, Planning Commission (2014), and exclusion of the emissions from agriculture and LULUCF (India, Planning Commission 2011).

[1] Australia's Cancun Pledge is based on the Kyoto Protocol, not UNFCCC classifications. As set out in table 4.2 of Australia (2022), Australia's net national emissions for the purpose of the Cancun Pledge were 500.9 $MtCO_2$-e in 2020.

[2] A complication with this table is that it presumes that Australia had a single year target. Australia's Pledge was a multi-year emissions budget from 2013 to 2020. As the table cannot accommodate an emissions budget pledge (relevant information provided in table 4.2 of Australia [2022]), to present it as a point target the 2020 Pledge case should be 527.7 $MtCO_2$-e.

[3] China's 2020 Pledge case assumes 40 per cent reduction in GHG intensity calculated based on the 2020 GDP cited in China (2012). The CO_2 projection is complemented for non-CO_2 projections from CAT (2015).

Indonesia [d]	No conclusion drawn	Chapter 2 (UNEP 2023) Official GHG inventory	UNEP (2017) based on Indonesia, Ministry of Environment (2010), Indonesia, Ministry of Environment and Forestry (2015) and Indonesia, Ministry of National Development Planning (2015).	Reduce emissions by 26% of BaU by 2020 (unconditional). 2020 Pledge case of 1,335[d] is calculated based on the baseline from Indonesia, Ministry of National Development Planning (2015).[4] 2,185[d] is calculated based on the baseline from Indonesia, Ministry of Environment (2010) and Indonesia, Ministry of Environment and Forestry (2015).
Japan [e]	Yes	Official GHG inventory [c]	Japan (2016) [5]	Reduce emissions by 3.8% below 2005 level by 2020.
Mexico [d]	No	Chapter 2 (UNEP 2023)	Mexico, Secretariat of Environment and Natural Resources (2013)	Baseline scenario pledge. In the intended nationally determined contribution (INDC) (Mexico 2015), Mexico has updated its baseline to 792. If the 2020 Pledge is calculated based on this baseline, it would be 555.[d]
Republic of Korea [e]	No	Republic of Korea, Greenhouse Gas Inventory and Research Centre (2022)	Republic of Korea (2016)	The Republic of Korea amended its Green Growth Basic Act to replace the 2020 pledge with the nationally determined contribution (NDC) target for 2030. Reduce emissions by 30% below BaU by 2020. 2020 Pledge case of 550[d] is calculated from INDC baseline of 783 (Republic of Korea 2015).
Russian Federation [d]	Yes	Official GHG inventory [c]	Frolov *et al.* (2014)	Reduce emissions by 15% below 1990 level by 2020. 2020 Pledge case reflects 25% reduction calculated based on national inventory data (Frolov *et al.* 2014).
Saudi Arabia [d]	No pledge	Chapter 2 (UNEP 2023)	No pledge	
South Africa [d]	Yes	Chapter 2 (UNEP 2023)	South Africa, Department of Environmental Affairs (2011) UNEP (2017)	None, assumed to follow BaU baseline scenario pledge.
Türkiye [d]	No pledge	Official GHG inventory [c]	No pledge	
United States of America [d]	Yes	Official GHG inventory [c]	United States of America, Department of State (2016)	Reduce GHG emissions to 17% below 2005 levels by 2020.

Source: Cancun Pledges in UNEP (2017).

[4] The INDC baseline is based on a revised national inventory that shows significantly lower 2010 emissions than those shown in Indonesia, Ministry of Environment (2010) and assumed by other studies cited here. See Indonesia, Ministry of National Development Planning (2015) for a comparison of 2010 emissions.

[5] In Japan (2016), Japan revised its accounting approach on LULUCF, which is now accounted for not only for the target year but also for the base year.

Notes:

[a] The emissions estimates of the 2020 Pledges are converted with GWPs from IPCC AR4.
[b] Figures based on GWPs from IPCC AR4 (IPCC, 2014)
[c] https://di.unfccc.int/time_series (September 2023)
[d] Figures including LULUCF
[e] Figures excluding LULUCF

B.2 Summary of GHG mitigation pledges in previous and new or updated NDCs by G20 members

Table B.2 Summary of GHG mitigation pledges in previous and new or updated NDCs by G20 members

G20 member (2015 emissions in brackets)	Previous NDC	New or updated 2030 Pledge	Change in 2030 emissions relative to previous NDC, based on modeling studies* (median and range)
G20 members that have submitted new or updated NDCs			
Argentina (0.38 $GtCO_2e$)	Cap 2030 net emissions at 483 $MtCO_2e$ (unconditional) and 369 $MtCO_2e$ (conditional).	Cap 2030 net emissions at 349 $MtCO_2e$ (unconditional).	-0.13 $GtCO_2e$ (range: -0.1– -0.13)
Australia (0.54 $GtCO_2e$)	Reduce GHG emissions by 26–28% from 2005 levels by 2030.**	Reduce GHG emissions by 43% from 2005 levels by 2030.	-0.1 $GtCO_2e$ (range: -0.16– -0.1)
Brazil (1.6 $GtCO_2e$)	Reduce GHG emissions by 37% from 2005 levels by 2025 and (indicatively) by 43% from 2005 levels by 2030.	Reduce GHG emissions by 50% from 2005 levels by 2030.	0.08 $GtCO_2e$ (range: -0.14–0.2)
Canada (0.73 $GtCO_2e$)	Reduce GHG emissions by 30% from 2005 levels by 2030.	40–45% below 2005 levels by 2030.	-0.25 to -0.06, with median staying at -0.15 $GtCO_2e$
China (11.7 $GtCO_2e$)	Peak CO_2 emissions around 2030. Reduce CO_2/GDP by 60–65% from 2005 levels by 2030. Share of non-fossil fuels in primary energy consumption to around 20% in 2030. Increase forest stock volume by around 4.5 billion m^3 in 2030.	Achieve CO_2 emissions peak before 2030 and carbon neutrality before 2060. Reduce CO_2/GDP by 65% from 2005 levels by 2030. Share of non-fossil fuels in primary energy consumption to around 25% in 2030.* Increase forest stock volume by around 6 billion m^3 in 2030. Total installed capacity of wind and solar power will reach above 1,200 GW by 2030.	-0.6 $GtCO_2e$ (range: -1.1–0.5)
EU27 (3.5 $GtCO_2e$)	Reduce GHG emissions by at least 40% from 1990 levels by 2030 (applied to EU28 collectively).	Reduce net GHG emissions by at least 55% from 1990 levels by 2030.	-0.7 $GtCO_2e$ (range: -0.8– -0.5)
India (2.66 $GtCO_2e$)	Reduce emissions/GDP by 33–35% from 2005 levels by 2030. Increase in share of non-fossil fuel in primary electricity production to 40% (conditional). Additional (cumulative) carbon sink of 2.5–3 $GtCO_2e$ by 2030.	Reduce emissions/GDP by 45% from 2005 levels by 2030. Increase in share of non-fossil fuel in primary electricity production to 50% (conditional). Additional (cumulative) carbon sink of 2.5–3 $GtCO_2e$ by 2030.	Reduced, but target still results in higher emissions than current policies scenario projections.

Indonesia (2.49 $GtCO_2e$)	Reduce GHG emissions by 29% (unconditional) and 41% (conditional) relative to BaU by 2030.	Reduce GHG emissions by 32% (unconditional) and 43% (conditional) relative to BaU by 2030.	-0.08 $GtCO_2e$ (range: -0.09– -0.08)
Japan (1.26 $GtCO_2e$)	Reduce GHG emissions by 26% from 2013 levels by 2030.	Reduce GHG emissions by 46% from fiscal year 2013 levels in fiscal year 2030, with efforts to reduce by 50%.	-0.28 $GtCO_2e$ (range: -0.3– -0.25)
Mexico (0.55 $GtCO_2e$)	Reduce GHG emissions by 22% (unconditional) and 36% (conditional) from BaU by 2030.	Reduce GHG emissions by 35% (unconditional) and 40% (conditional) from BaU by 2030.	-0.09 to 0.05, with median staying at around -0.5.
Republic of Korea (0.66 $GtCO_2e$)	Reduce GHG emissions by 37% from BaU by 2030.	Reduce GHG emissions by 40% from 2018 levels by 2030.	-0.1 $GtCO_2e$ (range: -0.11– -0.1)
Russian Federation (1.49 $GtCO_2e$)	Limit 2030 emissions to 70–75% of 1990 level.	Limit 2030 emissions to 70% of 1990 level.	Reduced, but target still results in higher emissions than current policies scenario projections. -0.05 $GtCO_2e$ (range: -0.15–0.0)
Saudi Arabia (617 $MtCO_2e$)	Annually abate up to 130 $MtCO_2e$ by 2030.	Annually abate up to 278 $MtCO_2e$ by 2030.	-0.25 $GtCO_2e$ (range: -0.6–0)
South Africa (0.52 $GtCO_2e$)	Limit 2025–2030 emissions to 398–614 $MtCO_2e$ (conditional).	Limit 2030 emissions to 350–420 $MtCO_2e$ (conditional).	-0.1 $GtCO_2e$ (range: -0.2 – 0.1)
Türkiye (0.40 $GtCO_2e$)	Reduce GHG emissions by up to 21% from BaU by 2030.	Reduce GHG emissions by up to 41% from BaU by 2030.	Reduced, but target still results in higher emissions than current policies scenario projections. -0.005 $GtCO_2e$ (range: 0.0– -0.03)
United Kingdom (0.51 $GtCO_2e$)	Contribution to EU28-wide at least -40% target	Reduce GHG emissions by at least 68% from 1990 levels by 2030.	-0.17 $GtCO_2e$ (range: -0.2– -0.1)
United States of America (6.12 $GtCO_2e$)	Reduce GHG emissions by 26–28% from 2005 levels by 2025.	Reduce GHG emissions by 50–52% from 2005 levels by 2030.	-0.8– -0.9 with median staying at -0.85 $GtCO_2e$.
Other			
Other non-G20			-1.0 $GtCO_2e$ (range: -1.6– -0.6)
Other factors			-0.4 $GtCO_2e$ (range: -0.8–0)
Global			-5.0 $GtCO_2e$ (range: -8.1– -1.6)

Sources: Climate Watch and Climate Action Tracker (CAT) (date: July 2022) and reduction estimates based on this study.

* Three model groups (den Elzen *et al*. 2022; Keramidas *et al*. 2022; Meinshausen *et al*. 2022; Meinshausen *et al*. 2023) and two open-source tools (CAT 2023; Climate Watch 2021).

** Australia's previous NDC of December 2020 provided an indicative emissions budget of 4832–4764 $MtCO_2e$ over the period 2021–2030. Australia's updated NDC, submitted to the UNFCCC on 16 June 2022, revised the commitment to both a single-year target to reduce emissions by 43 per cent below 2005 levels by 2030, and a multi-year emissions budget from 2021–2030. The indicative multi-year emissions budget is 4381 $MtCO_2e$ over the period 2021–2030.

B.3 Data sources for NDCs and country-level emissions projections

Official and independent sources for emissions data in 2030 under the NDC and current policies scenarios for G20 members are presented in table B.3.

Three main considerations informed the selection of studies projecting 2030 emissions: (1) taking into account of the most recent societal, economic and policy developments; (2) including peer-reviewed studies to the extent possible; (3) including studies published by national experts; and (4) covering all GHGs and sectors. On the first point, to take account of the most recent emission trends, the potential impact of recently implemented policies, and other global social and economic circumstances, the authors considered studies that were published in 2020 or later. Exceptions were made when external reviewers suggested national studies published before 2020, the emission projections of which are relevant for this assessment. Policy cut-off dates ranged from 2019 to early 2023 across studies, meaning that recently adopted policies, including those presented later in section 3.3.3, are reflected in some of the scenario studies reviewed here.

Table B.3 Official and independent sources for emissions data in 2030 under the NDC and current policies scenarios for the assessment of G20 members

Member	Updated or new NDC and other announced 2030 target: Official data sources (cut-off date: 25 September 2023)[1]	Current policies scenario: Official data sources[2]	Current policies scenario and NDC scenario: Independent sources: 1. Global models 2. National models
Argentina	UNFCCC (undated b)	N/A	1. Joint Research Centre (JRC) (Keramidas *et al.* 2022). Meinshausen *et al*. (2022; 2023) (NDC only). NewClimate Institute and International Institute for Applied Systems Analysis (IIASA) (Nascimento *et al*. 2022). 2. Blanco and Keesler (2022).
Australia	NC8/BR5 (UNFCCC undated a)	NC8/BR5 (UNFCCC undated a)	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL Netherlands Environmental Assessment Agency (PBL) (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. TIMES (Fragkos *et al.* 2022).[3]
Brazil	UNFCCC	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. Baptista *et al*. (2022).[3]
Canada	NC8/BR5	NC8/BR5	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. Canadian Climate Institute (Sawyer *et al*. 2022) (legislated/developing policies scenario).
China	N/A	N/A	1. CAT (2023). ENGAGE scenarios (three: Fujimori *et al*. 2021; Schmidt Tagomori *et al*. 2023; Schmidt Tagomori, Hooijschuur and Muyasyaroh 2023) JRC (Keramidas *et al*. 2022).

Member	Updated or new NDC and other announced 2030 target: Official data sources (cut-off date: 25 September 2023)[1]	Current policies scenario: Official data sources[2]	Current policies scenario and NDC scenario: Independent sources: 1. Global models 2. National models
			Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. National Center for Climate Change Strategy and International Cooperation (NCSC), Energy Research Institute (ERI) – Integrated Policy Assessment Model for China. NCSC and ERI scenarios are published in the COMMIT scenario database (IIASA 2021; van Soest *et al*. 2021). PECE (Fragkos *et al*. 2021).[4]
EU27	N/A[5]	NC8/BR5, EEA (2023)	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only).[6] PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023).
India	N/A	N/A	1. CAT (2023). ENGAGE scenarios (three: Fujimori *et al*. 2021; Schmidt Tagomori *et al*. 2023; Schmidt Tagomori, Hooijschuur and Muyasyaroh 2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. Asian-Pacific Integrated Model (AIM)/Hub (Fujimori *et al*. 2021). Indian Institute of Management (IIM) – AIM India (Vishwanathanan and Garg 2020). WRI and Energy Innovation (Swamy *et al*. 2021).
Indonesia	UNFCCC	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023).
Japan	UNFCCC	N/A[2]	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022). 2.[6]
Mexico	UNFCCC	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023).
Republic of Korea	UNFCCC	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022).[6]
Russian Federation	UNFCCC	NC8/BR4	1. CAT (2023). ENGAGE scenarios (two: Schmidt Tagomori *et al*. 2023; Schmidt Tagomori, Hooijschuur and Muyasyaroh 2023)[7] JRC (Keramidas *et al*. 2022).

Member	Updated or new NDC and other announced 2030 target: Official data sources (cut-off date: 25 September 2023)[1]	Current policies scenario: Official data sources[2]	Current policies scenario and NDC scenario: Independent sources: 1. Global models 2. National models
			Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. HSE – TIMES model (Roelfsama *et al*. 2020).
Saudi Arabia	N/A	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022).
South Africa	UNFCCC	N/A	1. CAT (2023). JRC (Keramidas *et al*. 2022). Meinshausen *et al*. (2022; 2023) (NDC only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023).
Türkiye	UNFCCC	N/A[2]	1. CAT (2023). JRC (Keramidas *et al*. 2022) (current policies scenario only). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023) (current policies scenario only).
United Kingdom	UNFCCC	United Kingdom, Department for Energy Security and Net Zero (2023)	1. CAT (2023). Meinshausen *et al*. (2022; 2023) (NDC only).
United States of America	UNFCCC	N/A[2]	1. CAT (2023). JRC (Keramidas *et al*. 2022). PBL (den Elzen *et al*. 2022; Nascimento *et al*. 2022; den Elzen *et al*. 2023). 2. Four scenarios from Bistline *et al*. (2023).[8]

Notes: N/A: not available.

[1] References provided only when the NDC emission levels are available in absolute terms.

[2] In this year's report, the authors included projections of four G20 members (Australia, Canada, the European Union and the United Kingdom) of the BR5s (for the Russian Federation and Türkiye, the BR4s) submitted to UNFCCC in 2023, as explained in section 3.4.1. For Japan and Türkiye, the "with existing measures" (WEM) scenario projections were examined in detail and excluded here, as they report NDC achievement scenario projections without clear indication of the policies that have been implemented to date (see definition of a current policies scenario in section 3.3). For the United States of America, the WEM projection of the BR5 estimate was excluded, as it excludes the impact of the Inflation Reduction Act.

[3] NDC target emission levels are recalculated to reflect the current NDCs.

[4] Augmented with historical non-CO_2 GHG emissions data from China's *First Biennial Update Report on Climate Change* (China 2016), combined with the median estimate of the 2010–2030 non-CO_2 emissions growth rates for China from five integrated assessment models (Tavoni *et al*. 2014), to produce economy-wide figures.

[5] EU27 does not provide official values for its NDC target including LULUCF and excluding international aviation and shipping. BR5 provides a figure excluding LULUCF and including international aviation and shipping; the REG scenario prepared for the Fit for 55 package assessment provided estimates excluding LULUCF (European Commission 2021).

[6] For EU27, Fragkos *et al*. (2021) was excluded because it provided emissions projections only for the EU28. For Japan, projections in Fragkos *et al*. (2021) and Fujimori *et al*. (2021) were excluded because their trajectories deviate

substantially already in 2020 compared to the estimate reported in the 2022 national GHG inventory report (UNFCCC 2022). For the Republic of Korea, the projections by Fragkos *et al*. (2021) were excluded due to similar reasons as for Japan.

[7] Minimum and maximum of the selected scenarios are considered. For India, two models are excluded due to large discrepancy (more than 20 per cent) in 2020 emission estimates compared to those presented in chapter 2. Similarly, only POLES and GCAM projections are included for Russian Federation. IMAGE projections are also excluded for both countries as they are represented by Nascimento *et al*. (2022).

[8] Models with full sector and gas coverage were considered (EPS-EI, GCAM-CGS, NEMS-RHG, RIO-REPEAT). These model projections are treated as individual studies for consistency with the 2022 assessment, in which earlier projections were represented as Rhodium Group (Larsen *et al*. 2022), REPEAT (Jenkins *et al*. 2022) and Energy Innovation (Mahajan *et al*. 2022).

B.4 Limitations of the analysis of G20 economies toward their NDCs

The most important caveats are similar to those of previous Emissions Gap Reports (adapted from den Elzen *et al*. 2019).

First, whether a country is projected to achieve or miss its Cancun Pledge or NDC targets with its existing policies depends on both the strength and stringency of the existing climate policy packages and the ambition level of the targets given structural factors (such as demographic and macroeconomic trends) that shape how easy or difficult a target is to achieve. Although targets have been assessed as diverging in ambition, this report does not assess the degree of each country's efforts to achieve a certain mitigation projection, and does not assess the ambition of the targets in the context of equity principles. Countries that are projected to achieve their NDCs with existing policies are therefore not necessarily undertaking more mitigation actions than countries that are projected to miss them, and vice versa.

Second, current policy scenario projections are subject to the uncertainty associated with macroeconomic trends, such as GDP, population growth and technological developments, as well as the impact of policies. Some pledges are also subject to the uncertainty of future GDP growth and other underlying assumptions. These all add to the fundamental uncertainty resulting from COVID-19.

B.5 Further explanations of indicators and coding criteria used for table 3.4

A green checkmark indicates the criterion is fulfilled; a yellow checkmark indicates the criterion is partially fulfilled or fulfilled to a lower level of robustness; a red X indicates the criterion is not fulfilled; "?" indicates the member has not provided information on the criterion (where relevant); *inconclusive* indicates inconsistency across data sources consulted; and *not evaluated* indicates the data sources consulted do not track data on the member.

Covers all sectors and *covers all gases* receive a green checkmark if the target covers all IPCC inventory sectors and all seven baskets of gases (CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorochemicals, sulfur hexafluoride and nitrogen trifluoride), and a red "X" otherwise.

Excludes international offsets receives a green checkmark if the G20 member states it will not use offsets, and a yellow checkmark if the member states that at this time it does not anticipate using offsets. *Separate removals targets* receive a green checkmark if the G20 member has set separate targets for gross emissions and gross removals, in addition to the net emissions target, and a red X otherwise.

Removals transparency refers to the G20 member's transparency regarding the role of removals in achieving its net-zero target, and receives a green checkmark if CAT codes it as containing "transparent assumptions for domestic LULUCF and separately for domestic removals and storage" and if the Net Zero Tracker (NZT) codes its carbon dioxide removal indicator as "yes", specifying what is included, or as "no", a yellow checkmark if CAT codes it as containing "non-transparent assumptions for domestic LULUCF and domestic removals and storage" and NZT codes its carbon dioxide removal indicator as "yes (unspecified)", and a red X if CAT codes it as "no information provided" and NZT as "not specified."

Published plan receives a green checkmark if CAT codes it as "underlying [government or government-endorsed] analysis identifies pathway and key measures for reaching net zero, with sector-specific detail" and NZT codes it as "green", a yellow checkmark if CAT codes it as "some information on anticipated pathway or measures for achieving net zero is available, but with limited detail" and NZT codes it as yellow, and a red X if CAT codes it as "no information provided" and NZT codes its plan indicator as red. For members not covered by CAT, the coding is based on NZT alone. Members are designated as "inconclusive" if different trackers reach differing conclusions.

Review process receives a green checkmark if CAT codes it as "yes," a yellow checkmark if CAT codes it as "yes, but non-legally binding or in the process of establishing a review cycle", and a red X otherwise.

Annual reporting receives a green checkmark if NZT codes as "annual reporting" and a red X otherwise. Members are designated as "inconclusive" if different trackers reach differing conclusions.

References

Australia (2022). *Australia's 8th National Communication on Climate Change: A Report Under the United Nations Framework Convention on Climate Change*. Canberra. https://unfccc.int/sites/default/files/resource/NatComm8%20Biennial%20Statement_2022_v8%2021%20Dec.pdf.

Baptista, L.B., Schaeffer, R., van Soest, H.L., Fragkos, P., Rochedo, P.R.R., van Vuuren, D. *et al*. (2022). Good practice policies to bridge the emissions gap in key countries. *Global Environmental Change* 73, 102472. https://doi.org/10.1016/j.gloenvcha.2022.102472.

Bistline, J., Blanford, G., Brown, M., Burtraw, D., Domeshek, M., Farbes, J. *et al*. (2023). Emissions and energy impacts of the Inflation Reduction Act. *Science* 380(6652), 1324-1327. https://doi.org/10.1126/science.adg3781.

Blanco, G. and Keesler, D. (2022). *Transición energética en la Argentina: Construyendo alternativas*. Buenos Aires: Centro de Tecnologías Ambientales y Energía, Facultad de Ingeniería, Universidad Nacional del Centro de la Provincia de Buenos Aires. https://farn.org.ar/wp-content/uploads/2022/09/DOC_UNICEN_FINAL_compressed-1.pdf.

Brazil (2010). Decreto No. 7.390, de 9 de Dezembro de 2010. http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2010/Decreto/D7390.htm. Accessed 13 November 2023.

Canada, Environment and Climate Change Canada (2016). *Canada's Second Biennial Report on Climate Change*. Gatineau. https://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/canadas_2nd_biennial_report.pdf.

China (2012). *Second National Communication on Climate Change of the People's Republic of China*. Beijing: National Development and Reform Commission. https://unfccc.int/resource/docs/natc/chnnc2e.pdf.

___________ (2016). *First Biennial Update Report on Climate Change of the People's Republic of China*. Beijing. http://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/submitted_burs/application/pdf/chnbur1.pdf.

Climate Action Tracker (2015). China. Berlin and Cologne: Climate Analytics and NewClimate Institute. https://climateactiontracker.org/media/documents/2018/4/CAT_2015-11-26_CountryAssessment_China.pdf.

__________ (2023). Countries, 30 August. https://climateactiontracker.org/countries/. Accessed 27 October 2023.

Climate Watch (2021). Explore determined contributions (NDCs). World Resources Institute. https://www.climatewatchdata.org/ndcs-explore. Accessed 19 February 2021.

den Elzen, M., Kuramochi, T., Höhne, N., Cantzler, J., Esmeijer, K., Fekete, H. *et al*. (2019). Are the G20 economies making enough progress to meet their NDC targets? *Energy Policy* 126, 238-250. https://doi.org/10.1016/j.enpol.2018.11.027.

den Elzen, M.G.J., Dafnomilis, I., Forsell, N., Fragkos, P., Fragkiadakis, K., Höhne, N. *et al*. (2022). Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach. Mitigation and Adaptation Strategies for Global Change 27, 33. https://doi.org/10.1007/s11027-022-10008-7.

den Elzen, M.G.J., Dafnomilis, I., Hof, A.F., Olsson, M., Beusen, A., Botzen, W.J.W. *et al*. (2023). The impact of policy and model uncertainties on emissions projections of the Paris Agreement pledges. *Environmental Research Letters* 18(5), 054026. https://dx.doi.org/10.1088/1748-9326/acceb7.

European Commission (2021). Excel files for REG scenario. https://energy.ec.europa.eu/publications/excel-files-reg-scenario_en. Accessed 14 November 2023.

European Environment Agency (2014). *Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014*. EEA technical report No. 9/2014. Copenhagen. http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2014.

__________ (2023). Member States' greenhouse gas (GHG) emission projections. https://www.eea.europa.eu/ds_resolveuid/e6cf1a5824ce4d69bbcf37951ac17541. Accessed 10 July 2023.

Fragkos, P., van Soest, H.L., Schaeffer, R., Reedman, L., Köberle, A.C., Macaluso, N. *et al*. (2021). Energy system transitions and low-carbon pathways in Australia, Brazil, Canada, China, EU-28, India, Indonesia, Japan, Republic of Korea, Russia and the United States. *Energy* 216, 119385. https://doi.org/10.1016/j.energy.2020.119385.

Frolov, A.V., Makosko, A.A., Blinov, V.G., Semenov, S.M., Nakhutin, A.I., Gitarsky, M.L. *et al*. (2014). *First Biennial Report of the Russian Federation: Submitted in Accordance with Decision 1/CP.16 of the Conference of the Parties to the United Nations Framework Convention on Climate Change*. Moscow: Federal Service for Hydrometeorology and Environmental Monitoring. http://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/1br_rus_unoffical_translation_eng.pdf.

Fujimori, S., Krey, V., van Vuuren, D., Oshiro, K., Sugiyama, M., Chunark, P. *et al*. (2021). A framework for national scenarios with varying emission reductions. *Nature Climate Change* 11(6), 472-480. https://doi.org/10.1038/s41558-021-01048-z.

Grassi, G., Conchedda, G., Federici, S., Viñas, R.A., Korosuo, A., Melo, J. *et al*. (2022). Carbon fluxes from land 2000–2020: Bringing clarity on countries' reporting. *Earth System Science Data* 14(10), 4643-4666. https://doi.org/10.5194/essd-14-4643-2022.

Gütschow, J., Günther, A. and Pflüger, M. (2021). The PRIMAP-hist National Historical Emissions Time Series (1750-2019) v2.3.1. Zenodo. https://zenodo.org/record/5494497#.Y0fwg3bMJD8. Accessed 13 October 2022.

India, Planning Commission (2011). *Low Carbon Strategies for Inclusive Growth: An Interim Report*. New Delhi. https://cstep.in/drupal/sites/default/files/2019-01/CSTEP_RR_Low_Carbon_Strategies_for_Inclusive_Growth_interim_report_2011.pdf.

__________ (2014). *The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth*. New Delhi. https://cstep.in/drupal/sites/default/files/2019-01/CSTEP_RR_Low_Carbon_Strategies_for_Inclusive_Growth_final_report_2014.pdf.

Indonesia, Ministry of Environment (2010). *Indonesia Second National Communication Under the United Nations Framework Convention on Climate Change.* Jakarta. http://unfccc.int/files/national_reports/non-annex_i_natcom/submitted_natcom/application/pdf/indonesia_snc.pdf.

Indonesia, Ministry of Environment and Forestry (2015). *First Biennial Update Report.* Jakarta: Directorate General of Climate Change. http://unfccc.int/resource/docs/natc/idnbur1.pdf.

Indonesia, Ministry of National Development Planning (2015). RAN-GRK Secretariat. https://web.archive.org/web/20160223095007/http:/ranradgrk.bappenas.go.id/rangrk/component/content/article/92-bahasa/informasi-sektoral/193-hasil-indc. Accessed 16 November 2023.

International Institute for Applied System Analysis (2021). IIASA COMMIT Scenario Explorer. https://data.ece.iiasa.ac.at/commit/#/workspaces/40. Accessed 4 July 2021.

Japan (2015). *Japan's Second Biennial Report Under the United Nations Framework Convention on Climate Change*. Tokyo. http://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/japan_br2_revised.pdf.

Jenkins, J.D., Mayfield, E.N., Farbes, J., Jones, R., Patankar, N., Xu, Q. *et al*. (2022). *Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022*. Princeton: ZERO Lab. https://repeatproject.org/docs/REPEAT_IRA_Prelminary_Report_2022-08-04.pdf.

Keramidas, K., Fosse, F., Diaz Rincon, A., Dowling, P., Garaffa, R., Ordonez, J. *et al*. (2022). *Global Energy and Climate Outlook 2022: Energy Trade in a Decarbonised World*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/863694.

Larsen, J., King, B., Kolus, H., Dasari, N., Hiltbrand, G. and Jones, W. (2022). A turning point for US climate progress: Assessing the climate and clean energy provisions in the Inflation Reduction Act. New York: Rhodium Group. https://rhg.com/research/climate-clean-energy-inflation-reduction-act/.

Mahajan, M., Ashmoore, O., Rissman, J., Orvis, R. and Gopal, A. (2022). Modeling the Inflation Reduction Act using the Energy Policy Simulator. San Francisco: Energy Innovation. https://energyinnovation.org/wp-content/uploads/2022/08/Modeling-the-Inflation-Reduction-Act-with-the-US-Energy-Policy-Simulator_August.pdf.

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R. *et al*. (2022). Realization of Paris Agreement pledges may limit warming just below 2 °C. *Nature* 604, 304-309. https://doi.org/10.1038/s41586-022-04553-z.

Meinshausen, M., Lewis, J., Nicholls, Z.R.J. and Guetschow, J. (2023). NDC factsheets. Zenodo. https://doi.org/10.5281/zenodo.8010081. Accessed 6 November 2023.

Mexico (2015). Intended nationally determined contribution. Mexico City. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Mexico/1/MEXICO%20INDC%2003.30.2015.pdf.

Mexico, Secretariat of Environment and Natural Resources (2013). *The National Climate Change Strategy: 10-20-40 Vision*. Mexico City. https://www.globalmethane.org/documents/The_National_Climate_Change_Strategy.pdf.

Nascimento, L., Kuramochi, T., Woollands, S., Moiso, M., de Villafranca Casas, M.J., Hans, F. *et al*. (2022). *Greenhouse Gas Mitigation Scenarios For Major Emitting Countries: Analysis of Current Climate Policies and Mitigation Commitments – 2022 Update*. Cologne and Berlin: NewClimate Institute for Climate Policy and Global Sustainability. https://newclimate.org/sites/default/files/2022-10/EC-PBL2022_CurrentPolicies_Oct22.pdf.

Republic of Korea (2016). *Submission by the Republic of Korea: Intended Nationally Determined Contribution.* Seoul. http://www4.unfccc.int/ndcregistry/PublishedDocuments/Republic%20of%20Korea%20First/INDC%20Submission%20by%20the%20Republic%20of%20Korea%20on%20June%2030.pdf.

Republic of Korea, Greenhouse Gas Inventory and Research Centre (2022). Announcement of 2022 national greenhouse gas inventory (1990–2020). In Korean. Seoul.

http://www.gir.go.kr/home/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=36&boardId=58&boardMasterId=2&boardCategoryId=.

Roelfsema, M., van Soest, H.L., Harmsen, M., van Vuuren, D.P., Bertram, C., den Elzen, M. *et al*. (2020). Taking stock of national climate policies to evaluate implementation of the Paris Agreement. *Nature Communications* 11(1), 2096. https://doi.org/10.1038/s41467-020-15414-6.

Sawyer, D., Griffin, B., Beugin, D., Förg, F. and Smith, R. (2022). *Independent Assessment: 2030 Emissions Reduction Plan*. Ottawa: Canadian Climate Institute. https://climateinstitute.ca/wp-content/uploads/2022/04/ERP-Volume-2-FINAL.pdf.

Schmidt Tagomori, I., Dafnomilis, I., Fricko, O., Richters, O., Bertram, C., Drouet, L. *et al*. (2023). ENGAGE Post-Glasgow Long-term Strategies. Version v1.0. Zenodo. https://doi.org/10.5281/zenodo.10009463. Accessed 14 November 2023.

Schmidt Tagomori, I., Hooijschuur, E. and Muyasyaroh, A. (2023). Promising climate progress. IIASA Policy Brief No. 34. Laxenburg: International Institute for Applied Systems Analysis. http://www.engage-climate.org/wp-content/uploads/2023/10/PB34_Engage-policy-briefweb_0.pdf.

South Africa, Department of Environmental Affairs (2011). *South Africa's Second National Communication under the United Nations Framework Convention on Climate Change*. Pretoria. http://unfccc.int/resource/docs/natc/zafnc02.pdf.

Swamy, D., Mitra, A., Agarwal, V., Mahajan, M. and Orvis, R. (2021). A tool for designing policy packages to achieve India's climate targets: Methods, data, and reference scenario of the India Energy Policy Simulator. Washington, D.C.: World Resources Institute. https://doi.org/10.46830/writn.21.00108.

Tavoni, M., Kriegler, E., Riahi, K., van Vuuren, D.P. *et al*. (2014). Post-2020 climate agreements in the major economies assessed in the light of global models. *Nature Climate Change* 5, 119-126. https://doi.org/10.1038/nclimate2475.

United Kingdom, Department for Energy Security and Net Zero (2023). Annex A. National Communication categories: Greenhouse gas emissions by source (revised 10 March 2023). In *Energy and Emissions Projections: 2021 to 2040*. London. https://www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040.

United Nations Environment Programme (2017). *The Emissions Gap Report 2017: A UN Environment Synthesis Report*. Nairobi. https://www.unep.org/resources/emissions-gap-report-2017

United Nations Framework Convention on Climate Change (2022). National Inventory Submissions 2022. https://unfccc.int/ghg-inventories-annex-i-parties/2022. Accessed 20 July 2022.

__________ (undated a). Fifth Biennial Reports – Annex I. https://unfccc.int/BR5. Accessed 1 July 2023.

__________ (undated b). NDC Registry. https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx. Accessed 10 July 2023.

United States of America, Department of State (2016). *2016. Second Biennial Report of the United States of America, Under the United Nations Framework Convention on Climate Change*. Washington, D.C. https://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/2016_second_biennial_report_of_the_united_states_.pdf.

van Soest, H., Reis, L.A., Baptista, L.B., Bertram, C., Després, J., Drouet, L. *et al*. (2021). Global roll-out of comprehensive policy measures may aid in bridging emissions gap. *Nature Communications* 12, 6418. https://doi.org/10.1038/s41467-021-26595-z.

Vishwanathan, S.S. and Garg, A. (2020). Energy system transformation to meet NDC, 2°C, and well below 2°C targets for India. *Climatic Change* 162, 1877-1891. https://doi.org/10.1007/s10584-019-02616-1.

Appendix C

Supplementary material for chapter 4: The emissions gap in 2030 and beyond

C.1 Extension of near-term policies and NDCs

Assessments of the implications of current policies and nationally determined contributions (NDCs) typically focus on the corresponding emissions levels by the year 2030. However, to understand their implications beyond 2030 and to estimate their global warming projections until 2100, these near-term estimates need to be extended. Studies apply different methods to carry out this extension. Here, we look at the methods used in the individual current policies and NDC studies assessed in this chapter and document the extension method used for the assessment presented in this report.

A variety of methods exist to extend near-term policies towards the end of the century. These include keeping the rate of emissions intensity improvement constant, or estimating the carbon price implied by current policies and NDC emissions reductions in 2030 and projecting this price forward until 2100 (Sognnaes *et al*. 2021). The individual modelling studies for current policies and NDCs that are assessed in this chapter all use the second method. Some keep carbon prices constant at their implied 2030 value throughout the twenty-first century (Keramidas *et al*. 2022). Others project carbon prices forward and assume an increase at a rate consistent with the growth in gross domestic product (GDP) (Dafnomilis, den Elzen and van Vuuren 2023; Schmidt Tagomori, Hooijschuur and Muyasyaroh 2023; van Ruijven *et al*. 2023). If no explicit integrated assessment model is used, a range of additional methods have been described (Gütschow *et al*. 2018). Climate Action Tracker (CAT) (2022) uses the "constant quantile extension" combined with information from the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) Scenario Database (Byers *et al*. 2022; Riahi *et al*. 2022).

For the assessment in this report, we use the standard method of extending current policies and NDCs throughout the century based on their implied carbon price by 2030. In line with the literature, carbon prices follow the same growth path as global GDP (van Soest *et al*. 2021). Following the method published by Rogelj *et al*. (2023), the emissions implied by these carbon price trajectories are estimated based on the relationships found in five modelling frameworks: MESSAGE-GLOBIOM 1.0, AIM/CGE 2.0, GCAM4.2, REMIND-MAgPIE 1.5 and WITCH-GLOBIOM 3.1. The median pathway across these five estimates is taken as the central estimate. In addition to this central assumption, we also explore how variations to the projected carbon price affect emissions by assuming a constant and 5 per cent annual growth in the carbon price, respectively. The respective minimum and maximum values across all five modelling frameworks determine the minimum–maximum ranges reported here.

This year's emissions extensions and temperature projections take a more robust approach compared to previous years, better accounting for the structural model uncertainties of emissions projections. Specifically, this year's estimates use all five modelling frameworks listed above, while earlier estimates selected only took the marker SSP2 implementation by MESSAGE-GLOBIOM 1.0. Because the latter model coincidentally happens to project the lowest emissions over the twenty-first century of the five models considered, this results in higher emissions and global temperature projections compared to previous years, even if all else would remain the same.

To estimate the impact of low-emission development strategies (LT-LEDS), the emissions projections following current policies or NDCs are adjusted following the method described in detail in Rogelj *et al*. (2023). The most optimistic case assumes the full implementation of all unconditional and conditional NDCs and all LT-LEDS, while the intermediate case assumes current policies and only those LT-LEDS that show *stronger implementation progress* (see table C.4).

The emissions and temperature estimation approach comprehensively covers two of the most important uncertainties in emissions projections: the degree to which near-term actions are continued after the near-term cut-off year (in this case, 2030), and the structure and dynamics of the applied models. These estimates are very consistent with other literature estimates, which fall well within the minimum–maximum ranges reported in this report. For example, CAT estimates current policies to lead to a central range of temperature outcomes of 2.6–2.9°C, with a best estimate of 2.7°C. This compares to this report's identical 2.7°C best estimate for the median warming outcome (50 per cent), and is clearly encompassed by this report's 1.8–3.5°C range due to assumptions post-2030 (table 4.4, 50 per cent). Furthermore, the International Energy Agency's delayed action case results in 1.7°C median warming by mid-century, whereas the comparable case in this report (i.e. the most optimistic case considering conditional NDCs and all LT-LEDS) indicates a best estimate of 1.8°C, but with a range of 1.6–2.3°C (table 4.4, 50 per cent). CAT reports a similar best estimate for its most optimistic scenario.

C.2 Tables

Table C.1 Complete set of scenarios for assessing and contextualizing the emissions gap

Category	Scenario cases	Cut-off year	Scenario description
Reference scenarios	Reference or year 2010 policies	2010	This scenario only covers climate policies implemented until 2010 and assumes the absence of any additional measures from 2010 onward.
	Current policies	2022	This scenario projects the greenhouse gas (GHG) implications of climate mitigation policies that have been adopted and implemented as of November 2022. These scenarios consider the short-term and mid-term socioeconomic impacts of COVID-19 and are, where necessary, adjusted for the impact of recent policies, such as the Inflation Reduction Act in the United States of America.
Updated NDC scenarios	Unconditional NDCs	2023	This scenario encompasses the most recent NDCs that have been identified to be implemented without any explicit external support (cut-off date: June 2023). The scenarios are adjusted for the updated NDCs since the last Emissions Gap Report (EGR), based on the estimated impact of chapter 3.
	Conditional NDCs	2023	In addition to the unconditional NDCs, this scenario encompasses most recent NDC targets that would be implemented upon receiving international support, such as finance, technology transfer and/or capacity-building (cut-off date: November 2022).
Mid-century scenarios	Current policies continuing	2022	As the current policies scenario above, and extended beyond 2030 assuming mitigation policies continues at a similar level of ambition (see section A..1)
	Unconditional NDCs with net-zero targets showing *stronger implementation progress*	2022	Scenario extending the current policies scenario, while including net-zero targets or LT-LEDS pledges that currently show stronger implementation progress (see sections 4.2.3 and A.1)
	Conditional NDCs plus all net-zero targets	2022	Most optimistic scenario assuming achievement of the conditional NDC scenario until 2030 and all net-zero or other LT-LEDS targets thereafter
Mitigation scenarios consistent with keeping warming below specific limits	Below 2°C	N/A	Least-cost pathway starting from 2020, and consistent with holding global warming below 2°C throughout the twenty-first century with at least 67 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 67 per cent chance.
	Below 1.5°C	N/A	Least-cost pathway ensuring that global warming is kept below 1.5°C with a minimum 33 per cent probability throughout the entire century, and is brought back below 1.5°C with at least 67 per cent probability by 2100.

Table C.2 Projected global GHG emissions of current policies ($GtCO_2e$) for the four selected studies after harmonization

Studies	2019	2030[a]	2035[a]	2050	References
CAT	57	56 (55–59)	56 (54–59)	55 (51–59)	CAT (2022)
PBL Netherlands Environmental Assessment Agency [b]	57	60*	61**	65**	den Elzen *et al*. (2022)* Nascimento *et al*. (2022)* Dafnomilis, den Elzen and van Vuuren (2023)**
Joint Research Centre	57	56	56	56	Keramidas *et al*. (2022)
ENGAGE [c]	57	56 (52–58)	57 (46–59)	57 (41–62)	Schmidt Tagomori, Hooijschuur and Muyasyaroh (2023) van Ruijven *et al*. (2023)
Median estimate	57	56 (52–60)	56 (46-61)	56 (41–65)	

Notes: GHG emissions expressed in CO_2e emission using AR6 100-year GWPs (Forster *et al*. 2021). Cut-off date of policies: about November 2022. 2030 estimates based on studies marked *. 2035 and 2050 estimates based on studies marked **.

[a] Minimum–maximum range.

[b] Adjusted to include the impact of Inflation Reduction Act in the United States of America.

[c] Minimum–maximum range includes estimates from four models, GEM-E3, MESSAGEix-GLOBIOM, REMIND-MAgPIE and WITCH, based on sensitivity analysis.

Table C.3 Projected global GHG emissions of updated NDC and current Pledges scenarios ($GtCO_2e$) for the four selected studies after harmonization

Scenarios	Unconditional NDCs	Conditional NDCs	Pledges	Pledges	
Studies	In 2030	In 2030	In 2035	In 2050	References
CAT [a]	54	50	46 (44–48)	30 (26–34)	CAT (2022)
PBL Netherlands Environmental Assessment Agency [b]	57 (54–57)*	55 (52–55)*	49**	21**	den Elzen *et al*. (2022)* Dafnomilis, den Elzen and van Vuuren (2023)**
Joint Research Centre		50	39	19	Keramidas *et al*. (2022)
Univ. Melbourne [a]	55 (54–57)	53 (52–54)			Meinshausen *et al*. (2022)
ENGAGE [a]			42 (35–46)	26 (17–28)	Schmidt Tagomori, Hooijschuur and Muyasyaroh (2023) van Ruijven *et al*. (2023)
Median estimate	55 (52–57)	52 (50–55)	44 (33–49)	23 (17–34)	

Notes: Adjusted to include the impact of the latest NDCs. Cut-off date of NDCs: June 2023. 2030 estimates based on studies marked *. 2035 and 2050 estimates based on studies marked **.

[a] Estimates represent median estimates and minimum–maximum range

[b] Estimates represent central estimates and minimum–maximum range.

Table C.4 Overview of LT-LEDS characteristics and assessment of implementation progress based on the assessment of key characteristics of G20 members' net-zero targets in chapter 3, table 3.4

Country	**Year**	**Target applicable to**	**Assessment of implementation plan**	**Current policies put emissions on downward trajectory by 2030 [a]**	**Assessment of net-zero target implementation progress**
Argentina	2050	GHG	Weaker	n	Weak
Australia	2050	GHG	Credible	n	Weak
Brazil	2050	Unclear	None	n	Weak
Cambodia	2050	CO_2	Credible	n	Weak
Canada	2050	GHG	Weaker	n	Weak
Chile	2050	GHG	Weaker	n	Weak
China	2060	CO_2	Weaker	n	Weak
Colombia	2050	GHG	Weaker	n	Weak
Egypt	N/A	N/A	N/A	n	Weak
Ethiopia	2050	Unclear	Weaker	n	Weak
European Union	2050	GHG	Credible	y	Stronger
India	2070	Unclear	Weaker	n	Weak
Indonesia	2060	Unclear	Weaker	n	Weak
Iran (Islamic Republic of)	N/A	N/A	N/A	n	Weak
Israel	2050	Unclear	None	n	Weak
Japan	2050	GHG	Weaker	y	Weak
Kazakhstan	2060	GHG	Weaker	n	Weak
Malaysia	2050	Unclear	Weaker	n	Weak
Mexico	2050	GHG	N/A	n	Weak
Morocco	2100	Unclear	None	n	Weak
Nepal	2045	CO_2	Weaker	n	Weak
New Zealand	2050	CO_2	Credible	y	Stronger
Nigeria	2060	GHG	Weaker	n	Weak
Republic of Korea	2050	Unclear	Credible	n	Weak
Russian Federation	2060	GHG	Weaker	n	Weak
Saudi Arabia	2060	Unclear	None	n	Weak
Singapore	2050	GHG	Weaker	n	Weak
South Africa	2050	CO_2	None	n	Weak
Thailand	2050	CO_2	Weaker	n	Weak
Türkiye	2053	Unclear	Weaker	n	Weak
Ukraine	2060	Unclear	None	n	Weak
United Arab Emirates	2050	Unclear	Weaker	n	Weak
United Kingdom	2050	GHG	Credible	n	Weak
United States of America	2050	GHG	Credible	y	Stronger
Viet Nam	2050	Unclear	Weaker	n	Weak

Notes:

[a] y is awarded if projected emissions under current policies are at least 10 per cent lower in 2030 than 2019 levels.

Table C.5 Projected global GHG emissions of current policies ($GtCO_2e$) for the mid-century scenario cases

Mid-century scenarios	2019	2030[a]	2035[b]		2040[b]		2050[b]	
			Individual Studies	EGR 2023 assess-ment	Individual studies	EGR 2023 assess-ment	Individual studies	EGR 2023 assess-ment
Current policies continuing	57	56 [52–60]	57 (46–61)	56 (52–58) [45–64]	57 (45–63)	56 (47–60) [38–68]	56 (41–66)	55 (44–56) [24–72]
Unconditional NDCs with LT-LEDS showing *stronger implementation progress*	57	55 [54–57]	N/A	53 (48–54) [46–59]	N/A	50 (42–53) [38–60]	N/A	44 (36–47) [26–58]
Conditional NDCs and all LT-LEDS targets (*most optimistic scenario*)	57	52 [50–55]	43 (35–50)	44 (41–44) [39–50]	38 (28–41)	36 (30–37) [27-45]	23 (17–28)	21 (17–25) [6–33]

Notes: GHG emissions expressed in $GtCO_2e$ emission using AR6 100-year GWPs (Forster *et al*. 2021).

[a] Median estimate and minimum–maximum range as assessed in section 4.2.2 from independent studies for 2030.

[b] Median best estimate across all model assumptions (minimum–maximum range) across median model estimates for best estimate extension of median 2030 values, and [minimum–maximum range] across different projection model assumptions and including 2030 current policy/NDC assessment uncertainty.

Table C.6 Global temperature projections for the year 2100 under the policy scenarios assessed in this chapter

Peak warming in 2100 (°C)			
Scenario	**66% chance**	**50% chance**	**90% chance**
Current policies continuing	3.0 (1.9–3.8)	2.7 (1.7–3.5)	3.5 (2.2–4.5)
Unconditional NDCs continuing	2.9 (1.9–3.7)	2.6 (1.8–3.4)	3.4 (2.3–4.4)
Conditional NDCs continuing	2.5 (1.7–3.6)	2.3 (1.6–3.3)	3.0 (2.0–4.2)
Unconditional NDCs and LT-LEDS with stronger implementation progress	2.7 (1.9–3.5)	2.5 (1.7–3.2)	3.2 (2.3–4.1)
Conditional NDCs and all LT-LEDS targets (most optimistic case)	2.0 (1.5–2.5)	1.8 (1.4–2.3)	2.4 (1.8–3.0)
Likelihood of limiting warming to below specific warming limit (%)			
Scenario	**1.5°C**	**2°C**	**3°C**
Current policies continuing	0 (0–25)	4 (0–78)	68 (16–99)
Unconditional NDCs continuing	0 (0–19)	6 (0–73)	75 (24–99)
Conditional NDCs continuing	0 (0–43)	19 (0–88)	90 (30–100)
Unconditional NDCs + LT-LEDS with stronger implementation progress	0 (0–24)	11 (0–78)	83 (42–99)
Conditional NDCs and all LT-LEDS (most optimistic case)	14 (1–67)	69 (22–96)	99 (89–100)

Notes: The range between brackets reflects the scenario uncertainty taking into account the range of emissions estimates for 2030 and the variations in their extensions (see section A.1 in the online appendix). The UNEP EGR typically presents the temperature projections and the avoidance of temperature limits at the 66 per cent chance level. Other likelihood levels are included for completeness.

References

Byers, E., Krey, V., Kriegler, E., Riahi, K., Schaeffer, R., Kikstra, J. *et al.* (2022). AR6 Scenarios Database. https://pure.iiasa.ac.at/id/eprint/18399/. Accessed 1 November 2023.

Climate Action Tracker (2022). Massive gas expansion risks overtaking positive climate policies: New CAT analysis shows LNG expansion plans threaten 1.5°C warming limit. Climate Action Tracker Warming

Projections Global Update. Berlin and Cologne: Climate Analytics and NewClimate Institute. https://climateactiontracker.org/documents/1094/CAT_2022-11-10_GlobalUpdate_COP27.pdf.

Dafnomilis, I., den Elzen, M. and van Vuuren, D.P. (2023). Achieving net-zero emissions targets: An analysis of long-term scenarios using an integrated assessment model. *Annals of the New York Academy of Sciences* 1522(1), 98-108. https://doi.org/10.1111/nyas.14970.

den Elzen, M.G.J., Dafnomilis, I., Forsell, N., Fragkos, P., Fragkiadakis, K., Höhne, N. *et al*. (2022). Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach. *Mitigation and Adaptation Strategies for Global Change* 27, 33. https://doi.org/10.1007/s11027-022-10008-7.

Forster, P., Storelvmo, T., Armour, K., Collins, W., Dufresne, J.-L., Frame, D. *et al.* (2021). The Earth's energy budget, climate feedbacks and climate sensitivity. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S. *et al.* (eds.). Cambridge and New York: Cambridge University Press. Chapter 7. 923-1054. https://doi.org/10.1017/9781009157896.009.

Gütschow, J., Jeffery, M.L., Schaeffer, M. and Bill Hare (2018). Extending near-term emissions scenarios to assess warming implications of Paris Agreement NDCs. *Earth's Future* 6(9), 1242-1259. https://doi.org/10.1002/2017EF000781.

Keramidas, K., Fosse, F., Diaz Rincon, A., Dowling, P., Garaffa, R., Ordonez, J. *et al*. (2022). *Global Energy and Climate Outlook 2022: Energy Trade in a Decarbonised World*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/863694.

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R. *et al*. (2022). Realization of Paris Agreement pledges may limit warming just below 2 °C. *Nature* 604, 304-309. https://doi.org/10.1038/s41586-022-04553-z.

Nascimento, L., Kuramochi, T., Woollands, S., Moiso, M., de Villafranca Casas, M.J., Hans, F. *et al.* (2022). *Greenhouse Gas Mitigation Scenarios For Major Emitting Countries: Analysis of Current Climate Policies and Mitigation Commitments – 2022 Update*. Cologne and Berlin: NewClimate Institute for Climate Policy and Global Sustainability. https://newclimate.org/sites/default/files/2022-10/EC-PBL2022_CurrentPolicies_Oct22.pdf.

Riahi, K., Schaeffer, R., Arango, J., Calvin, K., Guivarch, C., Hasegawa, T. *et al.* (2022). Mitigation pathways compatible with long-term goals. In *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Shukla, P.R., Skea, J., Reisinger, A., Slade, R., Fradera, R., Pathak, M. *et al.* (eds.). Cambridge and New York: Cambridge University Press. Chapter 3. 295-408. https://doi.org/10.1017/9781009157926.005.

Rogelj, J., Fransen, T., den Elzen, M., Lamboll, R.D., Schumer, C., Kuramochi, T. *et al.* (2023). Credibility gap in net-zero climate targets leaves world at high risk. *Science* 380(6649), 1014-1016. https://doi.org/10.1126/science.adg6248.

Schmidt Tagomori, I., Hooijschuur, E. and Muyasyaroh, A. (2023). Promising climate progress. IIASA Policy Brief No. 34. Laxenburg: International Institute for Applied Systems Analysis. http://www.engage-climate.org/.

Sognnaes, I., Gambhir, A., van de Ven, D., Nikas, A. Anger-Kraavi, A., Bui, H. *et al*. (2021). A multi-model analysis of long-term emissions and warming implications of current mitigation efforts. *Nature Climate Change* 11, 1055-1062. https://doi.org/10.1038/s41558-021-01206-3.

van Ruijven, B., Jäger, J., Riahi, K., Battersby, S., Bertram, C., Bosetti, V. *et al.* (2023). Chapter 7. In *ENGAGE Summary for Policymakers.* Laxenburg, Austria: International Institute for Applied Systems Analysis. 23-26. https://pure.iiasa.ac.at/id/eprint/19116/.

van Soest, H., Reis, L.A., Baptista, L.B., Bertram, C., Després, J., Drouet, L. *et al*. (2021). Global roll-out of comprehensive policy measures may aid in bridging emissions gap. *Nature Communications* 12, 6418. https://doi.org/10.1038/s41467-021-26595-z.

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