UN environment programme

# No more hot air ... please!

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

### Appendices

**Emissions Gap Report** 2024

ISBN: 978-92-807-4185-8
Job number: DEW/2672/NA
DOI: https://doi.org/10.59117/20.500.11822/46404



**Suggested citation**

United Nations Environment Programme (2024). Appendices. In *Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments.* Nairobi. https://doi.org/10.59117/20.500.11822/46404.

Production: Nairobi
URL: https://www.unep.org/emissions-gap-report-2024

**Co-produced with:**

UN environment programme | copenhagen climate centre

**Supported by:**

MINISTRY OF FOREIGN AFFAIRS OF DENMARK

Government of the Netherlands

# No more hot air ... please!

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

### Appendices

# Emissions Gap Report 2024

**Appendix A**

**Supplementary material for Chapter 2 - Global emissions trends**

## A.1 Uncertainties and methodological choices

Uncertainties in emissions estimates are reported following the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) Working Group III assessment of ±8 per cent for fossil carbon dioxide ($CO_2$), ±70 per cent for land use, land-use change and forestry (LULUCF) $CO_2$, ±30 per cent for methane ($CH_4$) and fluorinated gases (F-gases), ±60 per cent for nitrous oxide ($N_2O$) (Dhakal *et al.* 2022). Reflecting these uncertainties, global emissions estimates are rounded to the first decimal place of billions of tons of $CO_2$ equivalent, while current national emissions estimates are reported to three significant figures in millions of tons of $CO_2$ equivalent. Rates of change are reported to the first decimal place and fractions are rounded to the nearest 1.

Chapter 2 follows a territorial-based accounting of emissions (i.e. emissions are allocated to the sectors and nations where they occur) unless otherwise noted.

The latest years of emissions data should be treated as preliminary - particularly in the case of LULUCF $CO_2$ and non-$CO_2$ greenhouse gas (GHG) emissions - due to the use of provisional methodologies based on available activity data. Emissions are generally reported up to 2023. However, due to data limitations, this is not possible for inventory-based LULUCF $CO_2$.

## A.2 Emissions scope and sources

The calculation of global GHG emissions involves important choices on which sources are covered. In chapter 2 of this report, these choices are guided by four criteria: (1) the coverage of emissions sources should be as complete as possible, reflecting observed impacts on the climate system; (2) emissions sources should be human-driven (anthropogenic) and are therefore actionable and amenable to mitigation efforts by countries and societies; (3) emissions sources should have a net impact on the climate system, and should avoid processes in equilibrium (such as energy related biomass $CO_2$ emissions, which release emissions previously captured from the atmosphere by vegetation growth); and (4) emissions sources should ideally be tracked in national GHG inventories and fall under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC) process.

In practice, these criteria are not always mutually compatible. For instance, global bookkeeping estimates of LULUCF $CO_2$ are not compatible with national GHG inventories, due to varying definitions as highlighted in the main chapter text. A consequence of these choices is that the estimate of global GHG emissions differs in scope from estimates at a national level, typically because no disaggregated national data is available. These differences are highlighted in table A.1.

**Table A.1** Scope of emissions in global and national estimates.

| Gas | Source | Dataset | Included in global estimate? | Included in national estimates? |
|---|---|---|---|---|
| $CO_2$ | Energy and industry sectors | EDGARv9 | Yes | Yes |
| $CO_2$ | Cement carbonation | GCB 2023 | No | No |
| $CO_2$ | LULUCF (Global Bookkeeping) | GCB 2023 | Yes | No |
| $CO_2$ | LULUCF (National Inventory) | Grassi *et al.* | No | Yes |
| $CH_4$ | Energy, Industry, Agriculture and Waste sectors | EDGARv9 | Yes | Yes |
| $CH_4$ | LULUCF fire emissions | GFED | No | No |
| $CH_4$ | Other LULUCF emissions | - | No | No |
| $N_2O$ | Energy, Industry, Agriculture and Waste sectors | EDGARv9 | Yes | Yes |
| $N_2O$ | LULUCF fire emissions | GFED | No | No |
| $N_2O$ | Other LULUCF emissions | - | No | No |
| F-gases | UNFCCC F-gas species | EDGARv9 | Yes | Yes |
| F-gases | Ozone Depleting F-gas species | - | No | No |

*Sources:* Crippa *et al.* (2023) for EDGARv9; Friedlingstein *et al.* (2023) for GCB 2023; Grassi *et al.* (2022); van Wees *et al.* (2022) for GFED.

## A.3 Comparison of estimates with previous Emissions Gap Reports

Data from Emissions Database for Global Atmospheric Research (EDGAR) and the Global Carbon Budget are updated on a yearly basis using the latest available statistical information, thus providing the most updated time series on global GHG emissions. This implies changes compared with prior reporting in the Emissions Gap Report, as summarized in table A.2. All differences in total GHG emissions, as well as emissions by gas, between these reporting years are within the standard uncertainty ranges used by chapter 2.

One area of dataset development is to incorporate more detailed information on the technologies and abatement measures applied in each sector and various world regions. This is the case of the 2024 edition of the EDGAR data, where $CH_4$ emission estimates were revised for industrialized and developing countries to include disaggregated information on the emissions factors of on-shore and off-shore activities for gas and oil operations, as well as for waste activities. Overall these updates result in lower global annual $CH_4$ emissions by about ~1Gt $CO_2$ equivalent over the past decade, which remains within the uncertainty range of the EDGAR global GHG emissions (±10 per cent accuracy, 95 per cent confidence interval).

**Table A.2** Emissions in 2019 as reported in previous Emissions Gap Reports

| **$GtCO_2e$** | **Emissions Gap Report 2022** | **Emissions Gap Report 2023** | **Emissions Gap Report 2024** |
|---|---|---|---|
| **GHG** | 56.4 ± 5.4 | 56.9 ± 5.6 | 55.9 ± 5.5 |
| **Fossil $CO_2$** | 38 ± 3 | 37.8 ± 3 | 38.1 ± 3 |
| **LULUCF $CO_2$ (Bookkeeping)** | 3.8 ± 2.7 | 4.6 ± 3.2 | 4.6 ± 3.2 |
| **LULUCF $CO_2$ (Inventory)** | -1.9 ± -1.3 | -2.4 ± -1.7 | -2.8 ± -2 |
| **$CH_4$** | 10.6 ± 3.2 | 10.5 ± 3.2 | 9.3 ± 2.8 |
| **$N_2O$** | 2.6 ± 1.6 | 2.6 ± 1.5 | 2.5 ± 1.5 |
| **F-gases** | 1.4 ± 0.42 | 1.4 ± 0.42 | 1.4 ± 0.42 |

## A.4 On the use of national inventories versus third party emissions data

The Emissions Gap Report is intended to provide guidance that supports negotiations and countries to accelerate climate action, in the context of limiting global warming to well below 2°C. As such, one of the report's key objectives is to provide a timely update on "where do we stand?", including an update of emissions trends globally and for major emitters.

One of the challenges in providing this timely update is that national emissions inventories (hereafter 'inventories') are not usually available for the prior year at the time of publication. There are two reasons for this. First, whereas Annex I countries are required to submit inventories in the form of an annual National Inventory Report (NIR), non-Annex I countries do not face this requirement. Instead, non-Annex I countries may include inventory data in their Biannual Update Report (BUR), which is released every second year. Second, NIRs are typically published in the first to second quarter of each year, describing emissions that occurred two years prior. By contrast, the BURs can describe emissions that occurred multiple years prior (China's 2023 BUR, for instance, reports emissions in 2018). As a result of this, a compilation of data based on inventories would – in the best case – only be sufficient to report national emissions for selected countries two years prior to the time of publication. The last available global estimate may be many years prior.

The infrequency of inventory reporting is one of the reasons why third-party data has been developed to track global, national and sectoral emissions. Table A.1 describes a selection of these third-party datasets. The choice of EDGAR as the primary dataset for GHG gas emissions in chapter 2 reflects its comprehensive coverage of gases and timely update schedule, which can provide estimates for the prior year at the time of publication.

Besides the timing of inventories and third-party data releases, a key consideration is data quality. It can be argued that compared to third-party data, inventories often use more detailed methodologies and can apply country-specific emissions factors, reflecting considerable national investments in data gathering and analysis. This may especially be the case for Annex I countries, which have accumulated significant experience in reporting inventories. It should be noted that the EDGAR database used in this chapter is predominantly based on Tier 1 emission factors, whereas inventories often use more detailed Tier 2 or Tier 3 emission factors. On the other hand, a number of studies have found that inventories tend to diverge from top-down atmospheric inversions of $CH_4$ emissions, indicating that further improvements are needed in specific sectors such as agriculture, waste and fossil fuel production (Deng *et al.* 2022; Janardanan *et al.* 2024; Scarpelli *et al.* 2022; Tibrewal *et al.* 2024).

One way to overcome some of the limitations with these alternative sources would be to take a hybrid approach: inventory data could be used where it is available, while missing years are gap-filled with third-party data. However, this approach has not been adopted in this chapter for several reasons. First, it is important to maintain a clear distinction between inventories and third-party data, due to their conceptual and methodological differences, but also to appropriately reflect that different parties were involved in their production (national governments versus scientific communities). Second, it is not straightforward to integrate these different data sources, as third-party data uses projection methodologies that cannot be consistently applied to other datasets. And finally, as the Emissions Gap Report is an assessment of the latest science, it is important to prioritize traceability to the underlying peer reviewed literature and data, over the development of novel methodologies.

**Table A.3** Overview of selected global datasets of GHG emissions

| Dataset name | Version | Gases | Time period | Link |
|---|---|---|---|---|
| Emissions Database for Global Atmospheric Research (EDGAR) | 9.0 | $CO_2$-FFI, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, $NF_3$ | 1970-2023 | https://edgar.jrc.ec.europa.eu/ |
| Potsdam Real-time Integrated Model for probabilistic Assessment of emissions Paths (PRIMAP) | 2.5.1 | $CO_2$-FFI, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, $NF_3$ | 1750-2022 | https://zenodo.org/records/10705513 |
| Community Emissions Data System (CEDS) | 2024.04.01 | $CO_2$-FFI, $CH_4$, $N_2O$ | 1970-2022 | https://zenodo.org/records/10904361 |
| Global Carbon Budget (GCB) | 2024 | $CO_2$-FFI, $CO_2$-LULUCF | 1850-2023 (national); 1850-2024 (global) | https://globalcarbonbudget.org/ |

*Note:* These details are subject to change, as these datasets are in continuous development.

Therefore, while chapter 2 does not directly use national inventory estimates of GHG emissions, this choice is intended to be transparent. Further, as a basis of comparison to the third-party data that is used, where national emission totals are depicted, the latest inventory-based estimate is also shown.

## A.5 Data and code availability

The code and data used to produce all emissions estimates in this chapter are available here: https://github.com/lambwf/UNEP-Gap-Report-2024-Chapter-2.

## A.6 Additional tables

**Table A.4** Sources of GHG emissions by sector

| Sector and subsector | Key sources of emissions | IPCC 2006 categories |
|---|---|---|
| Energy: Power | $CO_2$ from fossil fuel combustion to generate electricity and heat in power plants. | 1A1a |
| Energy: Industry | $CO_2$ from fossil fuel combustion to drive on-site industrial processes, such as heating furnaces. | 1A2 |
| Energy: Transport | $CO_2$ from fossil fuel combustion in vehicles, including road transport, rail, aviation and shipping. | 1A3 |
| Energy: Buildings | $CO_2$ from fossil fuel combustion to provide on-site electricity or heat in commercial and residential buildings. | 1A4 |
| Energy: Fuel production | $CO_2$ from fossil fuel combustion for the refining of petroleum and other fuels, as well as 'fugitive' $CH_4$ emissions that are vented or leak from pipelines, wells and mines. | 1A1bc, 1A5, 1B |
| Industrial processes | Non-combustion $CO_2$ emissions from industrial processes, such as iron ore reduction and cement production, as well as the release of f-gases. | 2 |
| AFOLU: Agriculture | $CH_4$ and $N_2O$ from enteric fermentation in livestock such as cattle or sheep, biomass burning in fields, fertiliser application, rice cultivation and the management of soils. | 3A, 3C |
| AFOLU: Land use | $CO_2$ emissions from deforestation, logging, forest degradation, peat burning and drainage. Also includes $CO_2$ removals from afforestation, reforestation and shifting cultivation cycles. | 3B |

| | | |
|---|---|---|
| Waste & Other | $CH_4$ and $N_2O$ emissions from waste disposal, treatment and incineration. | 4, 5 |

**Table A.5** Trends in activity levels by sector and major emitter, 2017-2021

| | World | China | United States of America | India | European Union | Russian Federation |
|---|---|---|---|---|---|---|
| Power (%) | +2.1 | +5.9 | +0.1 | +3.1 | -0.9 | +0.9 |
| Industry (%) | +1.6 | +3.2 | +0.8 | +1.3 | -0.2 | +0.4 |
| Buildings (%) | +1 | +2.7 | +0.4 | +0.8 | -0.4 | +2.3 |
| Transport (%) | -2.4 | +2 | -2.1 | -0.6 | -2.1 | -0.8 |

*Note:* Power refers to total annual electricity generation, while industry, buildings and transport refer to total annual final energy consumption. Sources: EMBER (2024), IEA (2024).

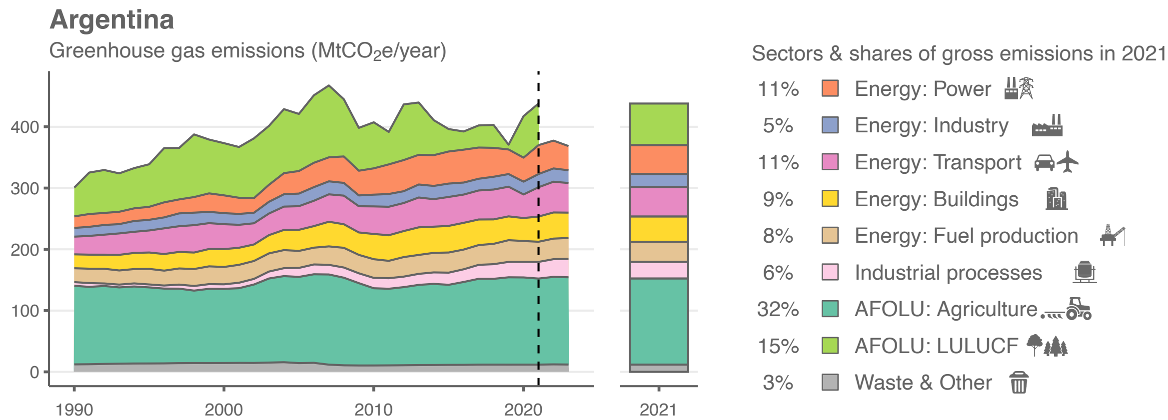
**Table A.6** Per capita activity levels by sector and major emitter in 2021

| sector | World | China | United States of America | India | European Union | Russian Federation |
|---|---|---|---|---|---|---|
| Power (kWh/capita) | 3,570 | 6,040 | 12,500 | 1,220 | 6,430 | 7,990 |
| Industry (GJ/capita) | 16.1 | 33.4 | 35 | 7.35 | 23.1 | 43.6 |
| Buildings (GJ/capita) | 15.7 | 14.1 | 59.8 | 5.43 | 35.2 | 54.6 |
| Transport (GJ/capita) | 14.3 | 10.3 | 76.1 | 3.04 | 25.7 | 28.3 |

*Note:* Power refers to total annual electricity generation, while industry, buildings and transport refer to total annual final energy consumption. Sources: EMBER (2024), IEA (2024).

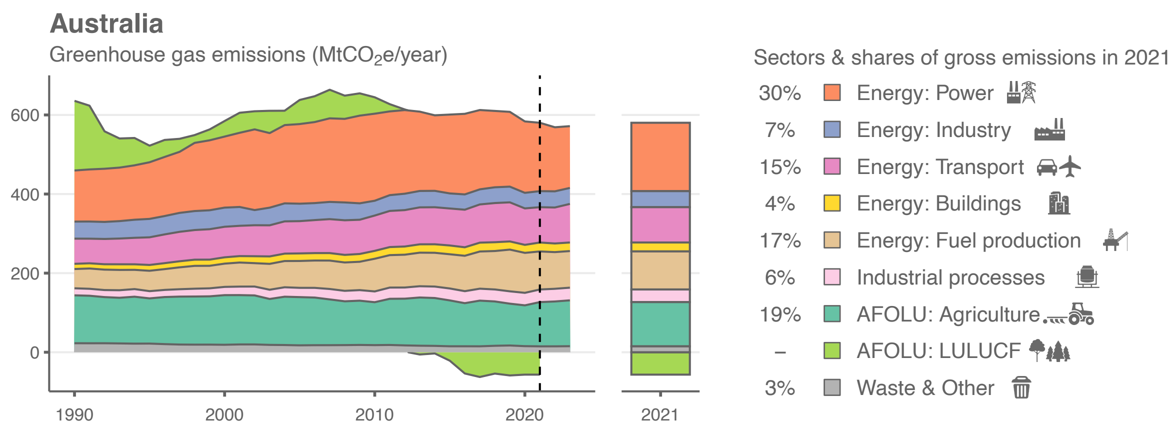
## A.7 Additional figures

### **Figure A.1** GHG emissions of Argentina



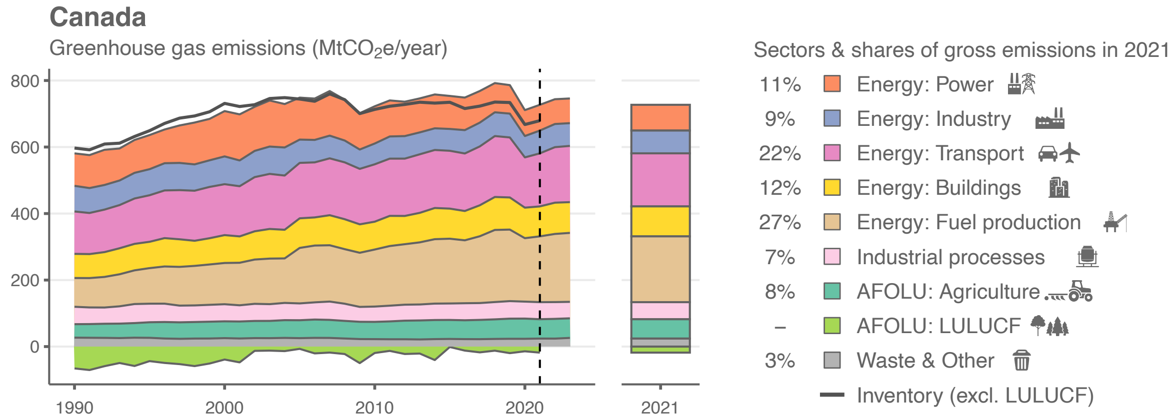

Argentina released an estimated 369 $MtCO_2e$ in 2023 (excluding LULUCF), a change of −2.4% compared to the previous year. Per capita GHG emissions were 7.9 $tCO_2e$ in 2023, while cumulative historic $CO_2$ emissions were 25.2 $GtCO_2$, representing about 0.98% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

### **Figure A.2** GHG emissions of Australia



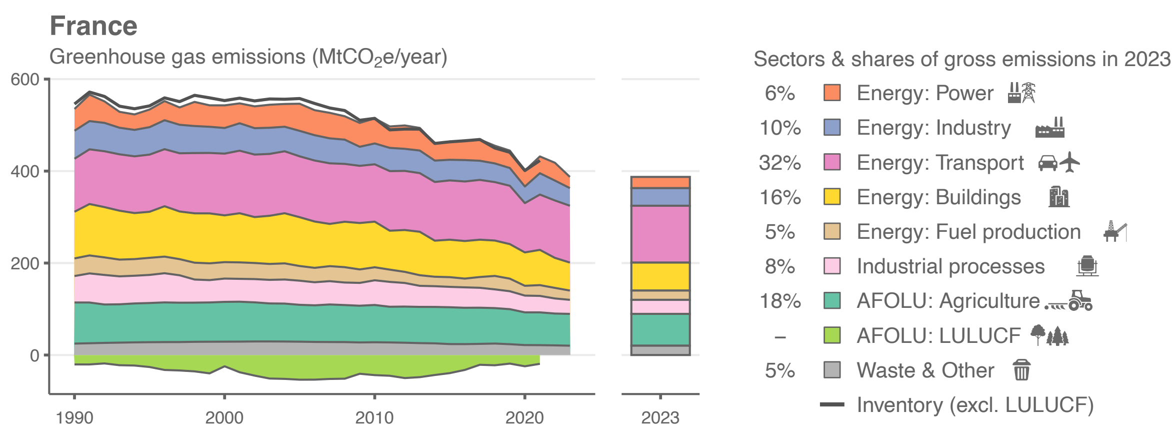

Australia released an estimated 572 $MtCO_2e$ in 2023 (excluding LULUCF), a change of +0.5% compared to the previous year. Per capita GHG emissions were 21 $tCO_2e$ in 2023, while cumulative historic $CO_2$ emissions were 32.3 $GtCO_2$, representing about 1.3% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.3** GHG emissions of Canada



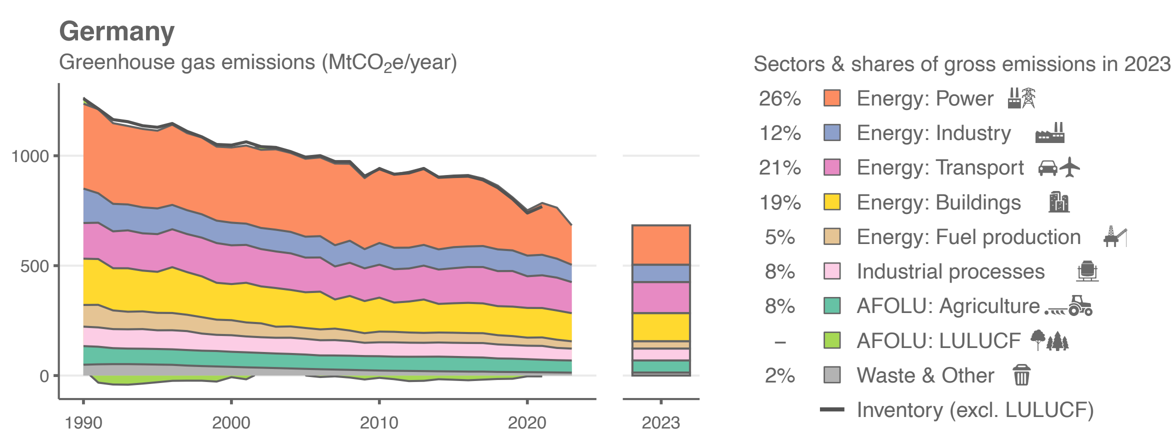

Canada released an estimated 746 $MtCO_2e$ in 2023 (excluding LULUCF), a change of +0.3% compared to the previous year. Per capita GHG emissions were 19 $tCO_2e$ in 2023, while cumulative historic $CO_2$ emissions were 61.9 $GtCO_2$, representing about 2.4% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.4** GHG emissions of France



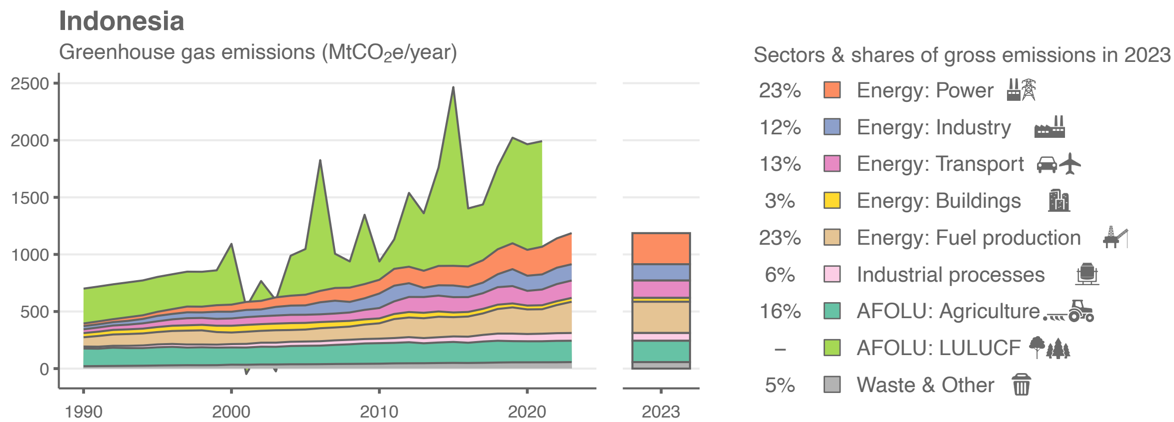

France released an estimated 387 $MtCO_2e$ in 2023 (excl. LULUCF), a change of –7.4% compared to the previous year. Per capita GHG emissions were 5.7 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 36.7 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.5** GHG emissions of Germany



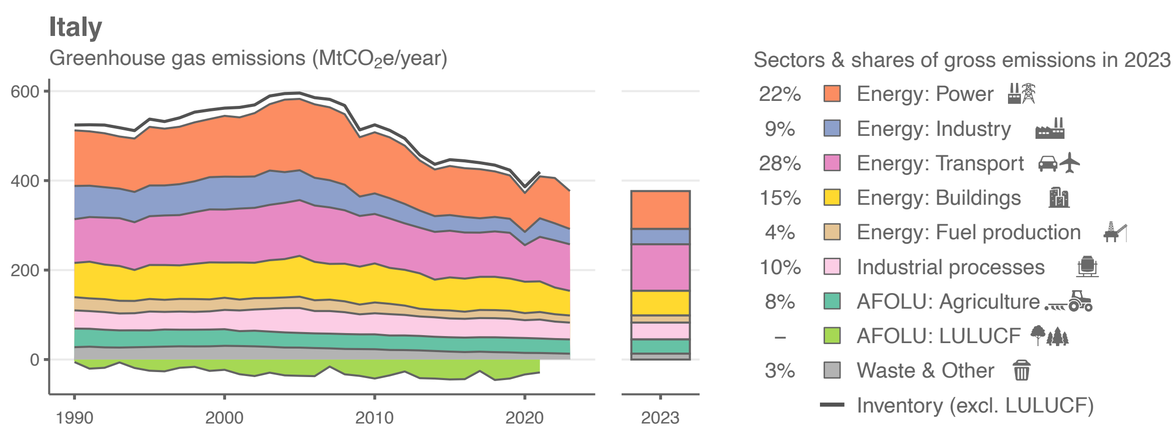

Germany released an estimated 683 $MtCO_2e$ in 2023 (excl. LULUCF), a change of –10.5% compared to the previous year. Per capita GHG emissions were 8.1 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 92.1 $GtCO_2$, or about 4% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.6** GHG emissions of Indonesia



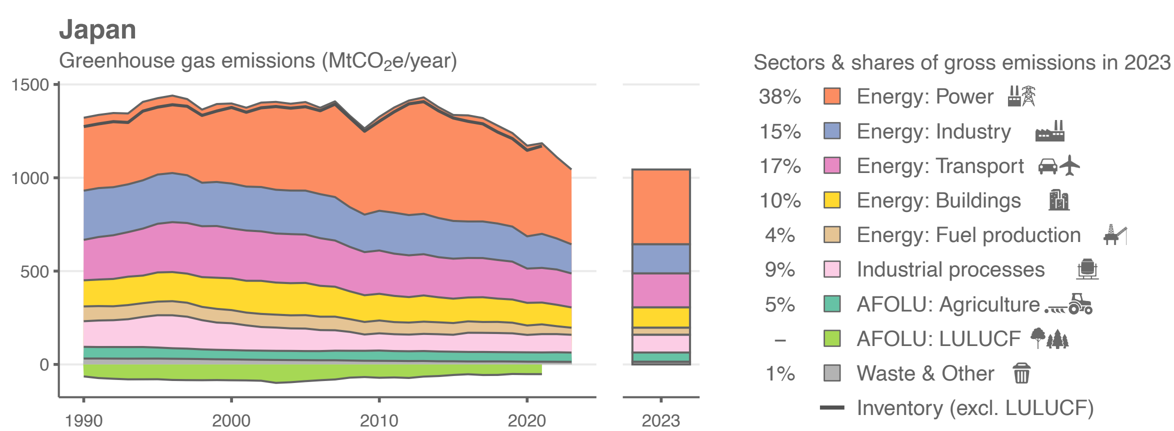

Indonesia released an estimated 1190 $MtCO_2e$ in 2023 (excl. LULUCF), a change of +4 % compared to the previous year. Per capita GHG emissions were 4.3 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 97.8 $GtCO_2$, or about 4% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.7** GHG emissions of Italy



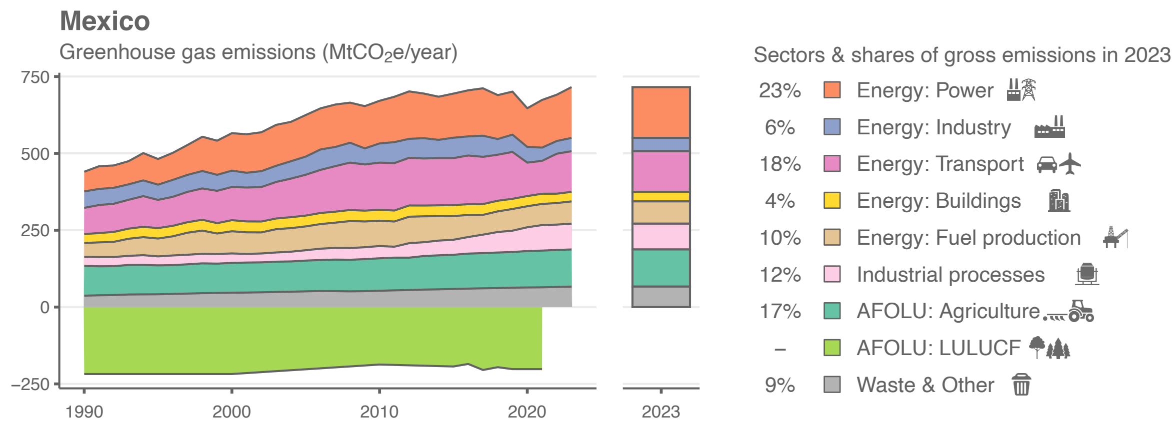

Italy released an estimated 377 $MtCO_2e$ in 2023 (excl. LULUCF), a change of −7.2% compared to the previous year. Per capita GHG emissions were 6.4 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 25.3 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.8** GHG emissions of Japan



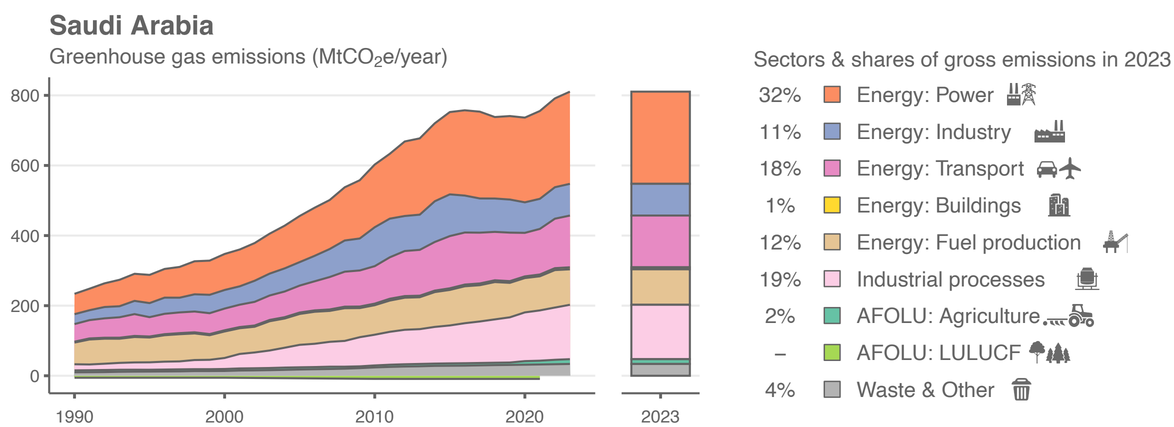

Japan released an estimated 1040 $MtCO_2e$ in 2023 (excl. LULUCF), a change of −6 % compared to the previous year. Per capita GHG emissions were 8.4 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 71 $GtCO_2$, or about 3% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

## Figure A.9 GHG emissions of Mexico



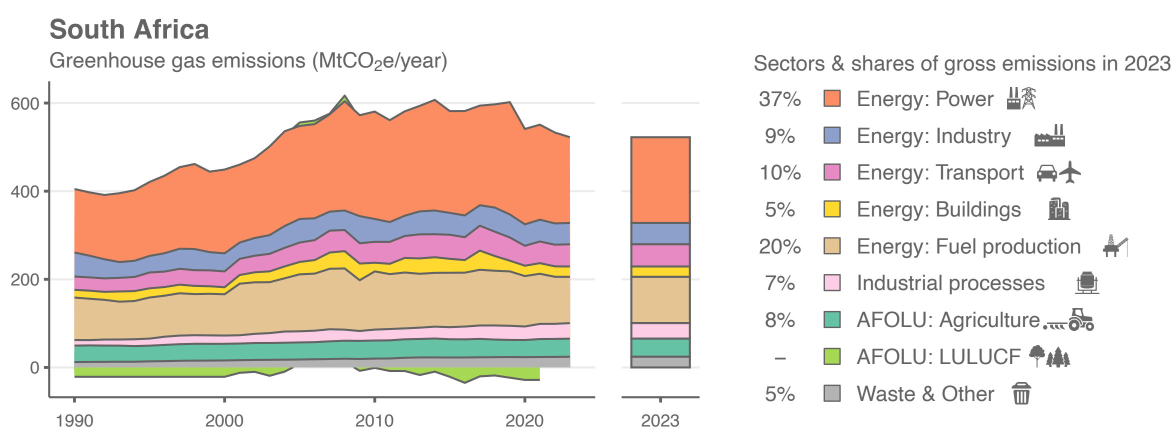

Mexico released an estimated 716 $MtCO_2e$ in 2023 (excl. LULUCF), a change of +3.6% compared to the previous year. Per capita GHG emissions were 5.6 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 31.1 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

## Figure A.10 GHG emissions of Saudi Arabia



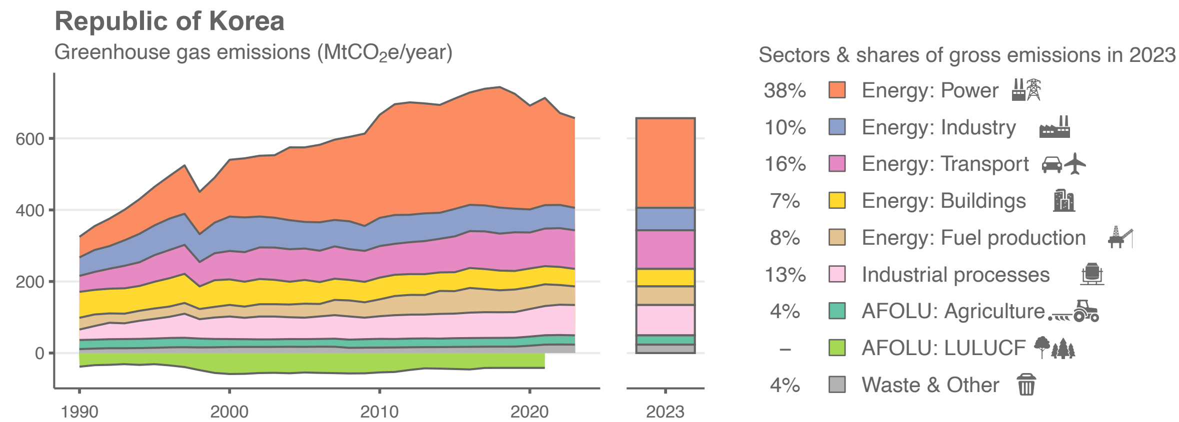

Saudi Arabia released an estimated 811 $MtCO_2e$ in 2023 (excl. LULUCF), a change of +2.4 % compared to the previous year. Per capita GHG emissions were 22 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 17.5 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

## Figure A.11 GHG emissions of South Africa



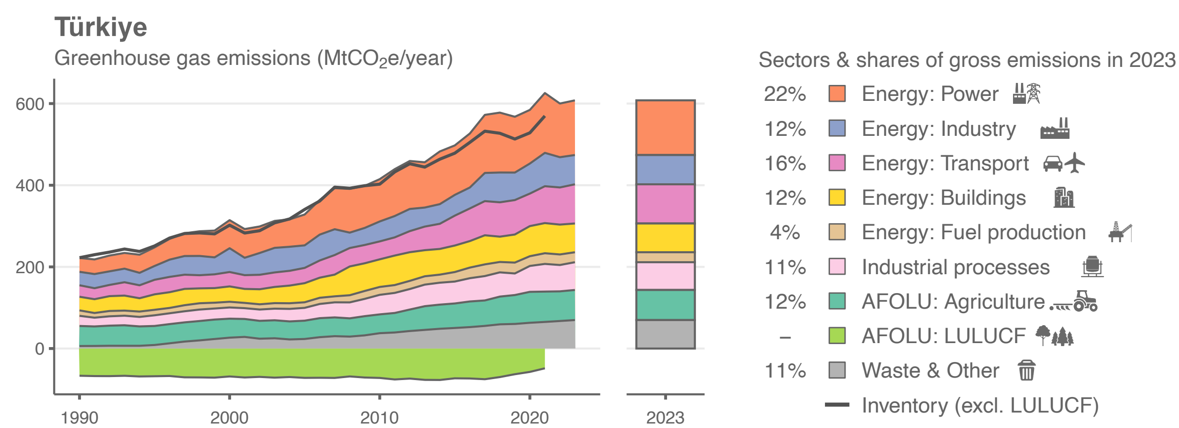

South Africa released an estimated 522 $MtCO_2e$ in 2023 (excl. LULUCF), a change of −2 % compared to the previous year. Per capita GHG emissions were 8.6 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 26.8 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.12** GHG emissions of Republic of Korea



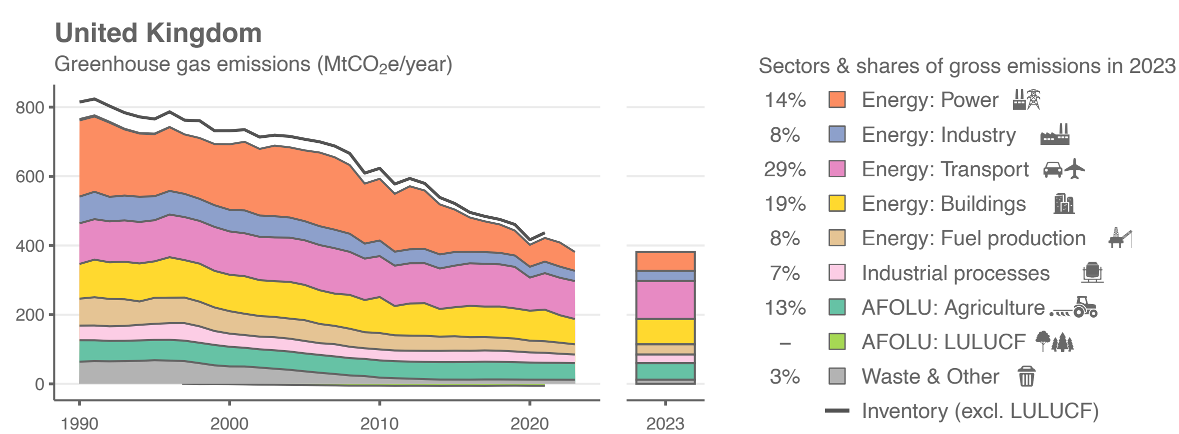

The Republic of Korea released an estimated 657 $MtCO_2e$ in 2023 (excl. LULUCF), a change of −2.1 % compared to the previous year. Per capita GHG emissions were 13 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 20.5 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.13** GHG emissions of Türkiye



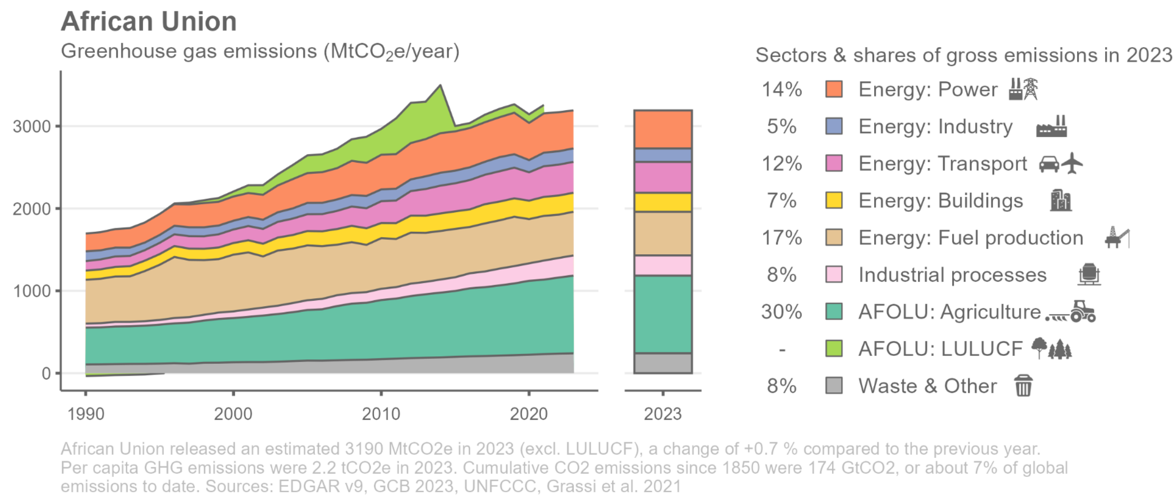

Türkiye released an estimated 608 $MtCO_2e$ in 2023 (excl. LULUCF), a change of +1.3 % compared to the previous year. Per capita GHG emissions were 7.1 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 14.1 $GtCO_2$, or about 1% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.14** GHG emissions of the United Kingdom of Great Britain and Northern Ireland




United Kingdom released an estimated 381 $MtCO_2e$ in 2023 (excl. LULUCF), a change of −6.7 % compared to the previous year. Per capita GHG emissions were 5.6 $tCO_2e$ in 2023. Cumulative $CO_2$ emissions since 1850 were 78.2 $GtCO_2$, or about 3% of global emissions to date. Sources: EDGAR v9, GCB 2023, UNFCCC, Grassi et al. 2021

**Figure A.15** GHG emissions of the African Union




## 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://edgar.jrc.ec.europa.eu/report_2023.GHG_emissions_of_all_world_countries_booklet_2023report.pdf.

Deng, Z., Ciais, P., Tzompa-Sosa, Z. A., Saunois, M., Qiu, C., Tan, C. *et al.* (2022). Comparing national greenhouse gas budgets reported in UNFCCC inventories against atmospheric inversions. *Earth System Science Data 14*(4), 1639–1675. https://doi.org/10.5194/essd-14-1639-2022.

Dhakal, S., Minx, J.C., Toth, F.L., Abdel-Aziz, A., Figueroa Meza, M.J., Hubacek, K. *et al.* (2022). Emissions trends and drivers. 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 2. 215-294. www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf.

EMBER (2024). *Yearly Electricity Data*. EMBER. https://ember-energy.org/data/yearly-electricity-data/. Accessed 22 November 2024.

Friedlingstein, P., O'Sullivan, M., Jones, M.W., Andrew, R.M., Bakker, D.C.E., Hauck, J., *et al.* (2023). Global carbon budget 2023. *Earth System Science Data* 15(12), 5301-5369. https://doi.org/10.5194/essd-15-5301-2023.

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

International Energy Agency (2024). World Energy Balances. www.iea.org/data-and-statistics/data-product/world-energy-balances. Accessed 9 October 2024.

Janardanan, R., Maksyutov, S., Wang, F., Nayagam, L., Sahu, S.K., Mangaraj, P. *et al.* (2024). Country-level methane emissions and their sectoral trends during 2009–2020 estimated by high-resolution inversion of GOSAT and surface observations. *Environmental Research Letters 19*(3), 034007. https://doi.org/10.1088/1748-9326/ad2436.

Scarpelli, T.R., Jacob, D.J., Grossman, S., Lu, X., Qu, Z., Sulprizio, M.P. *et al.* (2022). Updated Global Fuel Exploitation Inventory (GFEI) for methane emissions from the oil, gas, and coal sectors: evaluation with inversions of atmospheric methane observations. *Atmospheric Chemistry and Physics* 22(5), 3235–3249. https://doi.org/10.5194/acp-22-3235-2022.

Tibrewal, K., Ciais, P., Saunois, M., Martinez, A., Lin, X., Thanwerdas, J. *et al.* (2024). Assessment of methane emissions from oil, gas and coal sectors across inventories and atmospheric inversions. *Communications Earth & Environment* 5(1), 26. https://doi.org/10.1038/s43247-023-01190-w.

Van Wees, D., van der Werf, G.R., Randerson, J.T., Rogers, B.M., Chen, Y., Veraverbeke, S. *et al.* (2022). Global biomass burning fuel consumption and emissions at 500 m spatial resolution based on the Global Fire Emissions Database (GFED). *Geoscientific Model Development* 15(22), 8411–8437. https://doi.org/10.5194/gmd-15-8411-2022.

# Appendix B

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

### B.1 Methods underlying the Global Stocktake and NDCs categorization

For table 3.2 under 3.2 "Global trends in current NDCs provide important guidance for the next NDCs," a list of subsectors was identified in the Climate Watch dataset on sectoral mitigation measures in NDCs that were relevant to each of the global efforts listed in the first column. The number of NDCs that contained at least one measure related to at least one of the subsectors related to that effort was then determined according to the Climate Watch data. Climate Watch gathers this data directly from NDC documents by identifying all measures, targets, and policies within each NDC and coding the sectors and subsectors that each of these measures are related to. This dataset can be accessed through the Explore NDCs page or the Data Explorer at https://www.climatewatchdata.org/.

**Table B.1** Global effort items identified in the Global Stocktake and the indicators

| Global effort (Global Stocktake) | Notes and indicators used |
|---|---|
| Tripling renewable energy capacity by 2030 (28a) | All Energy/Renewable Energy indicators |
| Doubling global average annual rate of energy efficiency improvements by 2030 (28a) | All Energy/End Use indicators |
| Accelerating efforts towards the phase-down of unabated coal power (28b) | Energy/Fossil Fuels/Coal<br>Energy/Fossil Fuels/Phase-out/down |
| Accelerating efforts globally towards net zero emission energy systems (28c) | Energy/Renewable Energy<br>Energy/Other/Nuclear<br>Energy/Other/CCS<br>Energy/Other/Hydrogen<br>Hydrogen (Industries) |
| Transitioning away from fossil fuels in energy systems (28d) | Energy/Fossil Fuels/Phase-out/down |
| Accelerating zero- and low-emission technologies, including, inter alia, renewables, nuclear, abatement and removal technologies (28e) | Energy/Renewable Energy<br>Energy/Other/Nuclear<br>Energy/Other/CCS<br>Energy/Other/Hydrogen<br>Hydrogen (Industries) |
| Accelerating and substantially reducing non-carbon-dioxide emissions globally (28f) | Economy-wide/Gas/Methane<br>Economy-wide/Gas/SLCPs<br>Economy-wide/Gas/N2O<br>Economy-wide/Gas/F-gases |
| Accelerating the reduction of emissions from road transport (28g) | Energy/End use/Transport<br>Transport/General<br>Transport/Other<br>All Transport/Action indicators |

| | |
|---|---|
| | Road<br>Transport infrastructure<br>Improve: Electrification |
| Phasing out inefficient fossil fuel subsidies (28h) | No relevant indicators 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 greenhouse gases (33) | LULUCF/Conservation<br>LULUCF/Restoration<br>LULUCF/REDD+ |

## B.2 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.2.

Three main considerations informed the selection of studies projecting 2030 emissions: 1) consideration of the most recent societal, economic and policy developments, 2) include peer reviewed studies to the extent possible, 3) include studies published by national experts, and 4) covering all GHGs and sectors. On the first point, to account for the most recent emission trends, the potential impact of recently implemented policies, and other global social and economic circumstances, only studies that were published in 2022 or later were considered. Some of the studies excluded from this year's assessment include Fragkos *et al.* (2021) and Fujimori *et al.* (2021). Exceptions were made when external reviewers suggested national studies published before 2022, the emission projections of which are relevant for this assessment.

The approach to land-use emissions was adapted in this year's assessment to enhance alignment of land-use emission estimates with the definition of the LULUCF sector under national GHG inventories. For studies that do not use national GHG inventories (NGHGIs) as the basis for modelling (van Soest *et al* 2021; Schmidt Tagomori, den Elzen *et al.* 2023), we took their emission projections excluding land use.

The assumptions on LULUCF emissions in 2030 based on NGHGIs are updated and are presented in

Table B.3. For many countries, constant emissions between 2020 and 2030 are assumed for both NDC and current policies scenarios; this is a conservative estimation, as Nascimento *et al.* (2023), for example, projects reduced net emissions and enhanced net sinks for most countries. For three countries land-use emissions are considerably large compared to their energy and industry emissions (i.e. Argentina, Brazil, and Indonesia).

For studies that compiled projections from multiple integrated assessment models, additional considerations were made for consideration in the scenario synthesis. First, steps were taken to ensure that projections from a specific model is not overrepresented. For example, the IMAGE and POLES model projections from the two studies (van Soest *et al.* 2021; Schmidt Tagomori, den Elzen *et al.* 2023) were excluded, because these models are represented by more recent and standalone studies (Keramidas *et al.* 2023; Nascimento *et al.* 2023). Second, projections that are clearly contradicting the observed emission trends since 2015 were excluded. For example, one projection was excluded for showing continually declining emissions from 2015 through 2025 and another for showing a reduction of more than 10 per cent between 2020 and 2025. Third, projections that show 2020 emissions that are clearly inconsistent with the literature estimates (with a deviation of more than 10 per cent from the highest or lowest estimates of the three: PRIMAP including both NGHGI-based and third party-based and EDGAR).

**Table B.2** Official and independent sources for emissions data in 2030 under the NDC and current policies scenarios for the assessment of G20 members.

| Country | Updated or new NDC and other announced 2030 target: official data sources (cut-off date: 1 July 2024)[1] | Current policies scenario: Official data sources [2] | Current policies scenario and NDC scenario: Independent sources (1. global models and 2. national models) |
|---|---|---|---|
| **Argentina** | UNFCCC (2023) | N/A | 1. Climate Action Tracker (2024) (as reported in Nascimento *et al.* (2023)), Joint Research Centre (Keramidas *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **Australia** | Australia, Department of Climate Change, Energy, the Environment and Water (2023) | Australia, Department of Climate Change, Energy, the Environment and Water (2023) | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **Brazil** | UNFCCC | N/A | 1. Climate Action Tracker (2024) (as reported in Nascimento *et al.* (2023)), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only)<br>2. Baptista *et al.* (2022) [3] |
| **Canada** | Environment and Climate Change Canada (2023) | Environment and Climate Change Canada (2023) | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only)<br>2. Canadian Climate Institute (Sawyer *et al.* 2022) (legislated / developing policies scenario) |
| **China** | N/A | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), three ENGAGE scenarios ((Schmidt Tagomori, Dafnomilis, *et al.* 2023; Schmidt Tagomori, den Elzen *et al.* 2023) ; excl. LULUCF)[5], Meinshausen *et al.* (2023) (NDC only)<br>2. National Center for Climate Change Strategy and International Cooperation (NCSC; excl. LULUCF), Energy Research Institute (ERI) – Integrated Policy |

| Country | Updated or new NDC and other announced 2030 target: official data sources (cut-off date: 1 July 2024)[1] | Current policies scenario: Official data sources [2] | Current policies scenario and NDC scenario: Independent sources (1. global models and 2. national models) |
|---|---|---|---|
| | | | Assessment Model for China (IPAC; excl. LULUCF). NCSC and ERI scenarios are published in the COMMIT scenario database (IIASA 2021; van Soest *et al.* 2021) |
| **European Union** | European Environment Agency (EEA) (2023) [4] | EEA (2023) [4] | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023)(CP only), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **India** | N/A | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), four ENGAGE scenarios ((Schmidt Tagomori, Dafnomilis, *et al.* 2023; Schmidt Tagomori, den Elzen *et al.* 2023), four CP scenarios and two NDC scenarios, both excl. LULUCF))[5], Meinshausen *et al.* (2023) (NDC only) |
| **Indonesia** | UNFCCC | N/A | 1. Climate Action Tracker (2024) as reported in Nascimento *et al.* (2023)), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **Japan** | UNFCCC | N/A [2] | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **Mexico** | UNFCCC | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023) Meinshausen *et al.* (2023)(NDC only) |
| **Republic of Korea** | UNFCCC | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) [6] |
| **Russian Federation** | UNFCCC | NC8/BR4 | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), one ENGAGE scenario (GCAM, (Schmidt Tagomori, Dafnomilis, *et al.* 2023; Schmidt Tagomori, den Elzen *et al.* 2023), excl. LULUCF)[5], Meinshausen *et al.* (2023) (NDC only) |
| **Saudi Arabia** | N/A | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023)(NDC only), Meinshausen *et al.* (2023) (NDC only)<br>2. KAPSARC |
| **South Africa** | UNFCCC | N/A | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **Türkiye** | UNFCCC | N/A [2] | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023) |

| Country | Updated or new NDC and other announced 2030 target: official data sources (cut-off date: 1 July 2024)[1] | Current policies scenario: Official data sources [2] | Current policies scenario and NDC scenario: Independent sources (1. global models and 2. national models) |
|---|---|---|---|
| **United Kingdom** | UNFCCC | Department for Energy Security and Net Zero (2023) | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), Meinshausen *et al.* (2023) (NDC only) |
| **United States of America** | UNFCCC | N/A [2] | 1. Climate Action Tracker (2024), Joint Research Centre (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2022; Nascimento *et al.* 2023)<br>2. Four scenarios from Bistline *et al.* (2023)[6] |

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

[2] For Japan and Türkiye, the "with existing measures" (WEM) scenario projections of the 5th UNFCCC Biennial Reports were examined in detail and excluded here; they report NDC achievement scenario projections without a clear indication of the policies that are 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] The European Union (EU) does not communicate the official NDC target emission values including LULUCF and excluding international aviation and shipping in their submissions to the UNFCCC (e.g. updated NDC submission, 5th Biennial Report), but the European Environmental Agency provides them. The EEA's With Existing Measures (WEM) scenario was considered as an official current policies scenario; note however that the EEA WEM scenario does not consider the full implementation of recent EU-level policies such as the REPowerEU plan at the member state level.

[5] Minimum and maximum of the selected scenarios are considered.

[6] 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), Energy Innovation (2017).

## Table B.3 Harmonization of GHG emission projections related to land-use emissions

| Country | NDC scenario | | Current policies scenario | |
|---|---|---|---|---|
| | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** |
| Argentina | Historical LULUCF (latest data year) | No official LULUCF-specific target available | Other | LULUCF as significant net emission source. Nascimento *et al.* (2023) LULUCF data by IIASA (harmonised to NGHGI data) for Climate Action Tracker and ENGAGE scenarios. |
| Australia | Historical LULUCF (latest data year) | No official LULUCF-specific target available, small LULUCF emissions, little difference between NDC and current policies LULUCF emissions projections for 2030 (den Elzen *et al.* 2022) | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| Brazil | Other | No official LULUCF-specific target available | Other | LULUCF as significant net emission source. |

| Country | NDC scenario | | Current policies scenario | |
|---|---|---|---|---|
| | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** |
| | | | | Nascimento *et al.* (2023) LULUCF data by IIASA (harmonised to NGHGI data) for Climate Action Tracker and ENGAGE scenarios. |
| Canada | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Large sink (based on the NGHGI), no considerable changes in emission trends expected up to 2030 | Historical LULUCF | Large sink (based on the NGHGI), no considerable changes in emission trends expected up to 2030 |
| China | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Large sink (based on the NGHGI), assumed no considerable change up to 2030. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| European Union | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Large sink (based on the NGHGI), assumed no considerable change up to 2030. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| India | Historical LULUCF (latest data year) | No official LULUCF-specific target available | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| Indonesia | NDC LULUCF | Official LULUCF-specific target available | Other | Nascimento *et al.* (2023) LULUCF data by IIASA (harmonised to NGHGI data) for Climate Action Tracker and ENGAGE scenarios. |
| Japan | NDC LULUCF | Official LULUCF-specific target available | NDC LULUCF | LULUCF as net sink (based on the NGHGI). Little difference between NDC and current policies LULUCF emissions projections for 2030 (den Elzen *et al.* 2022). |
| Mexico | NDC LULUCF | Taking absolute numbers as indicated in the previous NDC, assume they stay the same for conditional target and for the subsequent NDC. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| Russian Federation | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Large sink (based on the NGHGI), assumed no considerable change up to 2030. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| Saudi Arabia | Historical LULUCF (latest data year) | No official LULUCF-specific target available. | Historical LULUCF | Negligible LULUCF emissions. |
| South Africa | Historical LULUCF (latest data year) | No official LULUCF-specific target available. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| Republic of Korea | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Small LULUCF emissions. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |

| Country | NDC scenario | | Current policies scenario | |
|---|---|---|---|---|
| | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** | **Harmonisation to LULUCF in case of only excl. LULUCF data** | **Notes** |
| Türkiye | NDC LULUCF | Official LULUCF-specific target available. | Historical LULUCF | LULUCF as net sink (based on the NGHGI), assumed no considerable change up to 2030. |
| United Kingdom | Historical LULUCF (latest data year) | No official LULUCF-specific target available. | Historical LULUCF | Small LULUCF emissions (based on the NGHGI), assumed no considerable change up to 2030. |
| United States of America | Historical LULUCF (latest data year) | No official LULUCF-specific target available. Large sink (based on the NGHGI), assumed no considerable change up to 2030. | Historical LULUCF | Large sink (based on the NGHGI), assumed no considerable change up to 2030. |

## B.3 Methods underlying the G20 net-zero pledges assessment

The indicators and criteria by which G20 net-zero pledges are assessed are as follows:

- Source: refers to whether the net-zero target is established in law, in a policy document (including an NDC or a long-term strategy), or via a political announcement or pledge, such as those made at the 2020 Climate Ambition Summit.
- Target year: refers to the year by which the source indicates net-zero emissions will be achieved.
- Covers all sectors and gases: receives green checkmark if the source specifies that the target applies to all economic sectors (as opposed to, for example, the energy sector only) as well as all Kyoto greenhouse gases. Receives yellow checkmark if full coverage is met for one of the two indicators (i.e., gases or sectors) tracked in this column, but not both.

Transparent information on carbon removal: Receives green checkmark if the source contains transparent assumptions for both domestic LULUCF and domestic removals and storage; receives yellow checkmark if source contains information on domestic LULUCF, removals and storage, but assumptions are not transparent.

- Published plan: receives green checkmark if source meets all Climate Action Tracker and Net Zero Tracker criteria for information on anticipated pathway or measures for achieving net-zero target, and a yellow checkmark if source meets some, but not all, criteria.
- Review process: receives a green checkmark if source establishes a legally binding process to review progress against the target at regular intervals; receives a yellow checkmark if the process is not legally binding, is still being established, or lacks detail or tracking of progress.
- Annual reporting: receives a green checkmark if source establishes a process to report at least annually on progress towards the target.

All indicators receive an "X" if the criteria for either a green or yellow checkmark are not met, a question mark where not enough information is available, an "inconclusive" if the data sources reach differing conclusions regarding the indicator and a "not evaluated" if none of the data sources track the indicator for the G20 member. The European Union is evaluated according to its long-term strategy, while individual European Union Member States are evaluated according to the laws, policies and plans specific to the respective States. Further detail on the methods underlying each indicator can be found at Climate Action Tracker, Climate Watch and Net Zero Tracker.

Table 3.4 in chapter 3 is a meta-analysis compiled from three independent sources. Data for each indicator are compiled and reconciled as follows:

*Source and target year:*

Data for the source and target year columns are derived from Climate Watch, the Net Zero Tracker, and Climate Action Tracker. In cases of discrepancies between the trackers, the source that is most binding and its corresponding target year is reported, with law more binding than policy document and policy document more binding than government announcement. It is important to note here, however, that the durability and credibility of targets communicated in law, policy document, or government announcement may vary depending on the governance structure of particular countries.

*Sector and gas coverage:*

Data for sectoral coverage are derived from Climate Watch ("coverage of domestic sectors" indicator), while data for gas coverage are derived from Climate Watch ("coverage of GHGs" indicator), the Net Zero Tracker ("greenhouse gases" indicator), and Climate Action Tracker ("emissions coverage" indicator). In cases of discrepancies between the three trackers which provide data for gas coverage, we report consensus if two out of the three trackers agree.

*Transparent information on carbon removal:*

Data for the transparent information on carbon removal column are derived from the Net Zero Tracker ("plans for carbon removal" indicator) and Climate Action Tracker ("carbon dioxide removal" indicator). In cases of discrepancies between the two trackers, we report the less-ambitious code as a conservative measure if the trackers disagree on whether the code should be yellow or green, though mark the country as "inconclusive" if one tracker codes the indicator as red.

*Published implementation plan:*

Data for the published plan column are derived from the Net Zero Tracker ("published plan" indicator) and Climate Action Tracker ("comprehensive planning" indicator) and are reconciled according to the scheme described in the figure key (a country receives a green checkmark if source meets all Climate Action Tracker and Net Zero Tracker criteria for information on anticipated pathway or measures for achieving net-zero target, and a yellow checkmark if source meets some, but not all, criteria.)

*Review process:*

Data for the review process column are derived from the Climate Action Tracker ("review process" indicator).

*Annual reporting:*

Data for the annual reporting column are derived from the Net Zero Tracker ("annual reporting mechanism" indicator).

## B.4 Methods underlying the G20 peaking assessment

The methodology and assumptions used to determine whether G20 members' emissions have peaked follows work by Levin and Rich (2017). A country is considered have peaked if both of the following conditions are met:

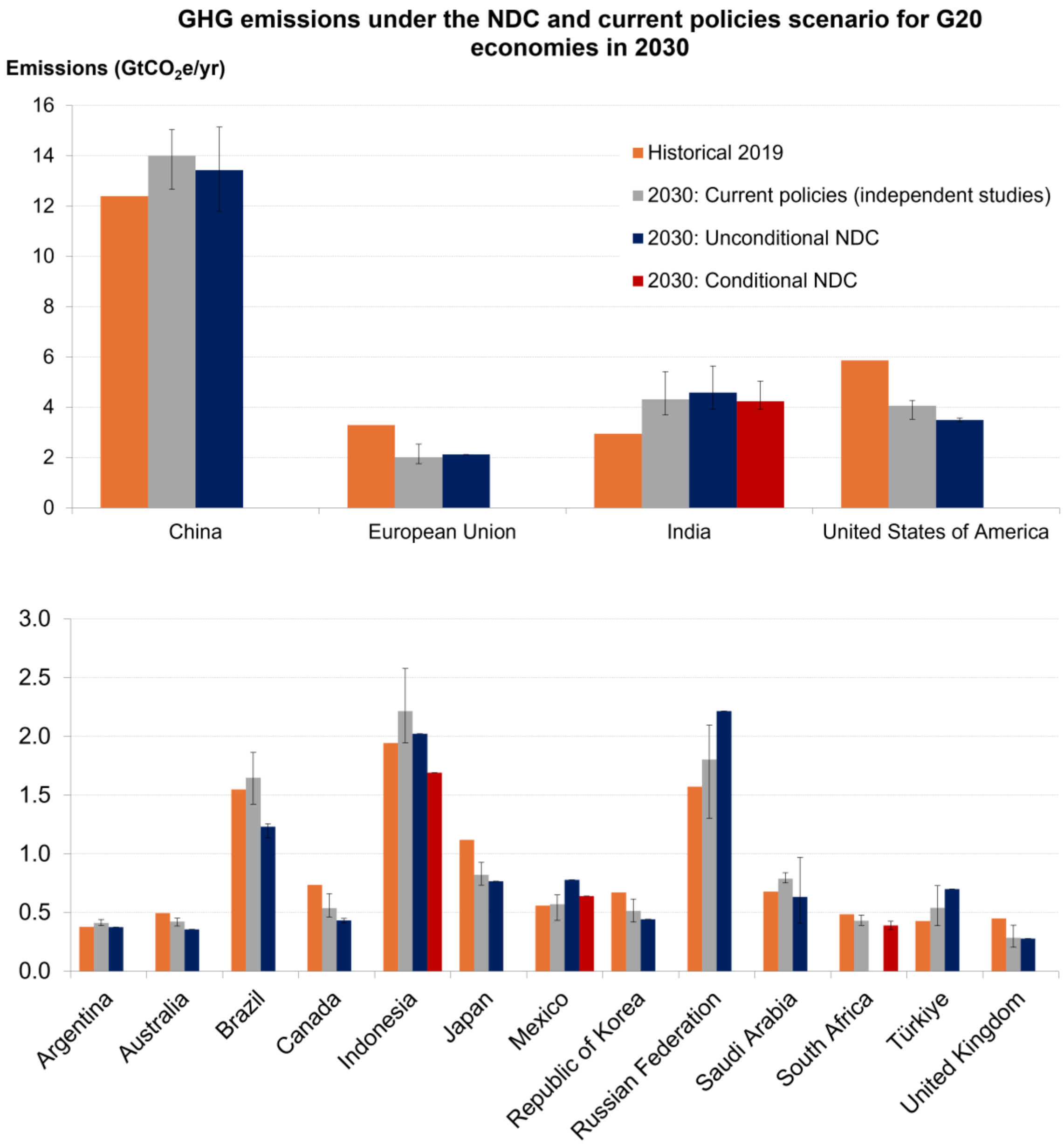
- Its net GHG emissions (including LULUCF) have reached maximum level at least five years before the most recent GHG inventory year. This includes emissions that increased again after the initial decline after peaking, as long as the emissions do not surpass the peaking level.
- The country has an unconditional commitment to continue to keep its emissions below the peak emissions level in the future.

Countries' peaking status is assessed based on historical data from Nascimento *et al.* (2024), which uses the most recent nationally reported inventory data (e.g. from national inventory reports, biennial update reports, or other national sources) for non-LULUCF sectors and Grassi *et al.* (2023) for LULUCF. The peak-year analysis includes LULUCF emissions for ease of comparison with net-zero target years, because net-zero targets also consider LULUCF emissions. Because LULUCF emissions fluctuate significantly, however, this approach introduces a degree of arbitrariness to the specific peak-year designation. For instance, Brazil's peak year is 2004 because LULUCF emissions were exceptionally high that year (2482 $MtCO_2e$, as compared to 1257 $MtCO_2e$ in 2002 and 1480 $MtCO_2e$ in 2005).

The rate of emissions change from 2019 through 2030 and from 2030 through the net-zero year is calculated using 2019 data from Nascimento *et al.* (2024) and 2030 data from Section 3.3 of this chapter. For countries categorized as not having peaked yet, the maximum time from peaking to net zero is calculated as the latest possible net-zero year minus the earliest possible peak year. If the country has stated a peak year, that year is considered as its earliest possible peak year.

## B.5 Supplementary figure

**Figure B.1** Implementation gaps between current policies and NDC pledges for the G20 members collectively and individually by 2030.




*Notes:* Bars show the central estimates, which are the median values when five or more studies were available, otherwise mean values, following den Elzen *et al.* (2019). The error bars show the uncertainty range across independent studies, which reflects model variations as well as interpretation of policies and targets. For NDCs, official values (adjusted to AR6's GWPs) are presented where available, without the range across independent studies shown as error bars. For the G20 total, the bar for unconditional NDCs also includes the conditional NDCs of South Africa.

## B.6 Developments in domestic policy

This section provides non-exhaustive recent policy updates observed between June 2023 and June 2024 across selected G20 members — ordered alphabetically. The data-driven approach of previous sections is complimented with snapshots of how climate policy developed in the past year across G20 countries. Cross-border effects of the presented policies were not explicitly considered. These policies cover only a fraction of the G20 policies and that other policies, including those without a direct climate motivation, may still result in substantial emissions reductions and support the implementation of more stringent policies over time.

Climate policy advanced in many areas during 2023, but their effects may be partially cancelled out by contradicting policies or developments within or outside countries' respective borders (also see e.g., Nascimento, Godinho, *et al.* 2024). As a result, some policy updates might not be directly measurable in countries' economy-wide emissions, although they advance domestic climate policy. There were also limited number of recently adopted domestic policies that were quantified or analysed in publicly available studies to have positive or negative effects in reducing national NDC implementation gaps.

**Argentina:** In July 2023, Argentina announced its Energy Transition National Plan for 2030 (Argentina, Ministry of Economy Secretariat of Energy 2023). The plan set out policies for the energy sector to achieve goals such as the emission limit of the NDC, an 8 per cent reduction in energy demand, and a minimum of 50 per cent renewable electricity generation. The plan also includes action areas for expanding fossil gas, hydrogen, and nuclear in the energy mix. In December 2023, a new administration took office in Argentina. Two of the initial actions of the administration were to propose a law known as 'Ley Ómnibus,' which was adopted in June 2024 (Argentina, National Congress 2024).This law sets up a Large Investment Incentive Regime (RIGI, in Spanish), which gives fiscal and economic benefits to extractive industries in the energy and agro-industrial sectors for 30 years. The administration also passed the Decree of Necessity and Urgency 70/2023, which, among other measures, eliminates the Fiduciary Fund for the Development of Distributed Generation, which has the aim to promote distributed generation systems from renewable sources through loans, incentives, guarantees and other financial instruments (Argentina 2023).

**Brazil:** Brazil re-established the Amazon Deforestation Prevention and Control Plan (PPCDAm) which, combined with other measures enacted in 2023, reduced Amazon deforestation rates by 22 per cent in 2023 (Brazil, Ministry of Environment and Climate Change 2023). Brazil also relaunched the Action Plan for the Prevention and Control of Deforestation in the Cerrado (PPCerrado), which addresses land-use conversion in Brazil's most active agricultural frontier. In August 2023, Brazil also introduced an economy-wide "Ecological Transformation Plan," which outlines a vision and instruments to support economic growth, social inclusion, and environmental preservation (Brazil, Ministry of Finance 2024). In the energy sector, Brazil progressed its renewable energy, which accounts for around 50 per cent of the total energy supply and 90 per cent of the electricity supply. The installed electricity generation capacity grew between 2022 and 2023, with significant decreases in thermal generation from natural gas and oil products. This was driven by substantial increases in solar (+68.1 per cent) and wind generation (+17.4 per cent). Other policies under development include the National Energy Transition Plan and the National Hydrogen Program (PNH2) — both important in Brazil's energy transition. Brazil also started to elaborate a new national climate change plan to inform the 2035 NDC and to update its National Plan for the Recovery of Native Vegetation (PLANAVEG) to restore at least 12 million hectares of native vegetation by 2030.

**Canada:** Canada continues implementing its 2030 Emissions Reduction Plan, which is the federal government's roadmap for achieving its 2030 target. In the past year, the federal government published final regulations for a zero-emissions light-duty vehicle sales mandate by 2035 and legislated investment tax credits for carbon capture and storage and clean technologies. Investment tax credits for technology manufacturing, clean hydrogen, clean electricity, and electric vehicle supply chain are also in development. Several other priority policies moved through the policy process but remain in development, including the proposed cap on oil and gas emissions, regulations for deeper methane reductions in the oil and gas sector, and clean electricity regulations. However, some recent decisions introduced uncertainty into the Canadian climate policy landscape. For instance, the Government of Alberta introduced new rules that will restrict renewable energy development and the federal government added uncertainty to carbon pricing by exempting home heating oil from the fuel charge. The government's official progress report concluded that Canada is projected to reduce emissions by 36 per cent below 2005 levels by 2030 — falling short of the target of 40 to 45 per cent (Canada 2023). An independent assessment concluded that Canada's emissions are projected to decline by 34 to 36 per cent below 2005 levels by 2030, underscoring that stronger policy is needed to close the gap (Sawyer *et al.* 2023).

**China:** In the past 12 months, the Chinese government has continued its efforts to achieve its carbon peaking and neutrality goals. In October 2023, the Ministry of Ecology and Environment (MEE) issued policies to regulate voluntary emission reduction activities (China, Ministry of Ecology and Environment 2023). The State Council also advanced the rules of its national carbon emission trading in 2024 (China, State Council 2024a). China also complements market approaches by regulating energy use and emissions in industry. In 2024, China announced an action plan for energy efficiency and carbon reduction in four major industries, iron and steel, oil production, ammonia, and cement. This plan specifies the main objectives of these key industries, including a reduction of about 30 million tons of coal, resulting in emissions reductions of about 80 $MtCO_2e$ in 2024-2025, and achieving a 30% share proportion of production above the benchmark level of energy efficiency by the end of 2025 (Haifeng 2024). China expects energy consumption and carbon dioxide emissions per unit of GDP to be reduced by about 2.5 and 3.9 per cent, respectively, in 2024 (China, State Council 2024b). The MEE also issued the methane emission control action plan in November 2023 to enhance the methane control policies, and the carbon footprint management action plan issued in June 2024 to improve the accounting standards and carbon footprint factor database.

**European Union:** The European Union updated its NDC in October 2023; it did not strengthen its 2030 GHG emission reduction target of at least 55 per cent below 1990 levels but it strengthened the policies and relevant targets that ensure that the target enshrined in the NDC is met. The updated NDC increases the target for forestry-related removals from 225 $MtCO_2e$ to 310 $MtCO_2e$. Over the past year, the European Union legislated the remaining components of its 'Fit for 55' policy package and REPowerEU plan ensuring that it has the legislative framework in place across all sectors to meet its 2030 NDC target. Among the most notable are the Renewable Energy and Energy Efficiency Directives. The Renewable Energy Directive strengthened the renewable energy target in the energy mix by 2030 from 32 to 42.5 per cent, with an additional 2.5 per cent indicative top-up, and increased sector-specific targets for renewables in transport, industry, and buildings (European Parliament and the Council of the European Union 2023b). The Energy Efficiency Directive set more ambitious energy efficiency targets (The European Parliament and the Council of the European Union 2023a). The European Union also adopted increased emissions reduction targets for its Effort Sharing Regulation and European Union Emissions Trading System (EU ETS) (Council of the European Union 2023).[1] The regulatory landscape is resolved at the EU-level but member states still need to translate and implement these measures at the national level.

**India:** In August 2023, under the National Green Hydrogen Mission, the government set the Green Hydrogen Standard, which outlines the emission thresholds for green hydrogen (India, Ministry of New and Renewable Energy and Council on Energy, Environment and Water 2024). India has also amended several policies in December 2023 to safeguard the supply of critical and strategic minerals. These include the Mines and Minerals (Development and Regulation) Amendment Act and the Offshore Areas Mineral (Development and Regulation) Amendment Act. In the past year, India also updated several energy policies. For example, it adopted the National Framework for Promoting Energy Storage Systems and communicated energy savings targets under the Perform Achieve and Trade (PAT) scheme (India, Ministry of Power 2023). The government also approved the expansion of the PM KUSUM Scheme with revised targets of 4.9 million solar-powered pumps for farmers and enhanced the Solar Park Scheme, which guides the development of larger solar power projects, from 20 GW to 40. India also progressed on several bioenergy policies. The government advanced its target of 20 per cent blending of bioethanol in petrol from 2030 to 2025-26 (India, Ministry of Petroleum and Natural Gas 2023). The 2023-24 budget of India's Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan) initiative announced 500 new plants to convert bio-waste into energy or other resources to support circularity (India, Ministry of Jal Shakti and Department of Drinking Water and Sanitation 2023). Finally, the government has also started using green bonds to mobilise resources for green infrastructure projects.

**Indonesia:** In 2023, the Indonesian government established its Emission Trading Scheme (ETS). Initially, the ETS covered only on-grid coal plants larger than 100 MW. In 2024, it was expanded to include on-grid coal plants larger than 25 MW and will be expanded further to include off-grid coal plants in 2025. The ETS will cover other fossil-based power plants by 2028. The ETS initial phase covered 99 power plants with a total capacity of 33 GW. The Ministry of Energy and Mineral Resources estimated the scheme could reduce up to 36 $MtCO_2$ annually by 2030. In November 2023, the Government of Indonesia and International Partners Group launched a Comprehensive Investment and Policy Plan (CIPP) for its Just Energy Transition Partnership (JETP), initiated in 2022. The first CIPP outlines the roadmap to reach the power sector's emission peak of 250 $MtCO_2$ by 2030 for on-grid power plants. The CIPP is being updated in 2024 to include emissions from captive power plants and energy efficiency measures. The original JETP target seeks to reach on-grid and captive power plant peaking emissions at 290 $MtCO_2$ by 2030. Meeting this target requires renewable shares of 34–40 per cent in 2030 — the range depends on the system's capacity for early coal plant retirement. The National Electricity Plan draft (RUKN) published in late 2023, indicates that renewables will reach 34 per cent of the electricity mix in 2030.

---

[1] http://data.europa.eu/eli/reg/2023/857/oj and http://data.europa.eu/eli/dir/2023/959/oj.

**Mexico:** In September 2023, the Ministry of Finance (SHCP) launched the Sustainable Finance Mobilisation Strategy, which offers various financial instruments to guide investments in low-carbon and climate-resilient measures. This strategy is projected to mobilise US$100 million annually from 2023 to 2030 and to significantly contribute to Mexico's climate change commitments (Mexico, Ministry of Finance and Public Credit 2023a; Mexico, Ministry of Finance and Public Credit 2023b). However, Mexico's energy policy moves in the opposite direction. For example, there have been limited renewable energy developments — also regarding the instruments needed to accelerate the energy transition. After two years delay, the new PEMEX refinery (Dos Bocas) began commercially distributing diesel (Mexico 2022). The government also continues expanding its gas pipelines in the north and southeast of Mexico (Espejo and Hilfiker 2020; Madry 2023). In June 2024, a new administration was elected. This presents an opportunity for the climate and energy transition agendas, which were prominently integrated into the campaign proposals.

**Republic of Korea:** The Republic of Korea continues implementing its plans to reach its carbon neutrality goal. Implementation plans include incorporating emissions reduction targets into national budget planning and the creation of a climate response fund to support the transition of carbon-intensive industries (Republic of Korea, Ministry of Environment 2023). In June 2024, the Ministry of Trade and Industry of the Republic of Korea revealed a draft of the 11th Basic Electricity Plan, which outlines the electricity supply and demand for the next 15 years. Electricity supply is projected to increase faster than previously estimated and nuclear power is projected to remain the largest source of electricity while renewables show almost no change from the 10th Basic Electricity Plan. The Korean emission trading system (K-ETS) will be revised in the next year to be aligned with the 2030 NDC — as the scheme for the third compliance period (2021-2025) will be concluded. Still, most hurdles lie in the slow phase-out of coal, liquefied natural gas reliance and the general fossil fuel lifetime extension with hydrogen and ammonia co-firing, which pose stranded asset and energy security risks.

**Saudi Arabia:** In 2024, Saudi Arabia started annual tenders for renewable energy projects with a total capacity of 20 GW aiming to reach between 100 to 130 GW by 2030. The Kingdom has 4 GW of renewable energy capacity connected to the grid, 8 GW under construction, and 7 GW in the financial close stage (Saudi Arabia, Ministry of Energy 2024). Saudi Arabia is also diversifying its electricity mix by shifting from oil to fossil gas. In 2023, four gas-fired power plants totalling almost 6 GW started operations. The Kingdom expands hydrogen production, for example through its Neom Green Hydrogen project, which has secured substantial investments and is planned to deliver hydrogen by the end of 2026 (Singh 2023). Additionally, Saudi Arabia implemented measures to reduce the local usage of diesel products by raising diesel prices by over 50 per cent since the beginning of 2024. This policy aims to encourage the adoption of cleaner alternatives and promote energy efficiency. In late 2023, Saudi Arabia announced its Greenhouse Gas Crediting & Offsetting Mechanism (GCOM) — a domestic carbon market to support emission reductions in line with the Kingdom's NDC and net-zero targets (Clean Development Mechanism Designated National Authority, n.d.). It also launched its Green Financing Framework, which defines project eligibility, and financial instruments, among others to support aligning domestic financial flows with the Paris Agreement (Saudi Arabia, Ministry of Finance 2023).

**United Kingdom:** The United Kingdom halved its greenhouse gas emissions between 1990 and 2022. However, the United Kingdom's independent Climate Change Committee warned in

2023 that recent developments make meeting the country's 2030 targets harder (Climate Change Committee 2023). Some of these developments include the policy announcements in September 2023 that delayed requirements for the phase-out of internal combustion engine vehicles new sales and targets on home efficiency. The government also missed tree planting targets, implying less carbon sequestration by 2050 (Braby 2024; Gabbatiss and Viisainen 2024). The next two renewable auction rounds will need to result in additional 21 GW to meet the United Kingdom target of 50 GW of wind capacity by 2030 (United Kingdom, Department for Energy Security and Net Zero and Department for Business and Trade 2023; Energy UK 2024). This average is higher than the capacity awarded in previous auctions. The United Kingdom had a general election after the cut-off date for literature and data assessed in this chapter. The new government has set out new ambitions for the UK to deliver clean power by 2030. It is also in the process of deciding whether to revise the budget for the sixth Allocation Round.

**United States of America:** In the last year, the United States Environmental Protection Agency (EPA) finalised three important regulations that, building on the passage of the Inflation Reduction Act and Infrastructure Investment and Jobs Act, will require reductions of greenhouse gas emissions in key segments of the US economy. In December 2023, EPA finalised limits on the methane emissions from new and existing oil and natural gas operations, which they estimate will reduce methane emissions by 1.5 $GtCO_2e$ from 2024-2038 and 130 million metric tons in 2030 (United States Environmental Protection Agency 2024a). In the transportation sector, EPA finalized regulations in March 2024 that reduce $CO_2$ emissions from light (LDV) and medium duty (MDV) vehicles beginning in model year 2027, building on previously enacted rules for model years 2023-2026 (United States Environmental Protection Agency 2024b). These rules will meaningfully increase the share of zero-emitting vehicles, with sales of light-duty ZEVs projected to make up 52 per cent of total LDV sales and 32 per cent of MDV sales in 2032 and will reduce GHG emissions by 7.2 $GtCO_2e$ over their lifetime. Finally, in April 2024, EPA enacted limits on carbon emissions from existing coal power plants and newly built gas power plants. EPA projects these limits will substantially reduce the contribution of unabated coal to the power mix by 2035, accelerate deployment of clean generating technologies, and lead to a reduction of 1.38 $GtCO_2$ from the power sector through 2047 (United States Environmental Protection Agency 2024c).

## References

Argentina (2023). *Bases para la reconstrucción de la Economía Argentina*, *Argentina.gob.ar*. http://www.argentina.gob.ar/normativa/nacional/decreto-70-2023-395521/texto.

Argentina, Ministry of Economy Secretariat of Energy (2023). *Resolución 517/2023*, *Legislación y Avisos Oficiales*. Buenos Aires. www.boletinoficial.gob.ar/detalleAviso/primera/289826/20230707.

Argentina, National Congress (2024). *Ley de Bases y Punto de Partida para la Libertad de los Argentinos*. Buenos Aires. www.boletinoficial.gob.ar/detalleAviso/primera/310189/20240708.

Australia, Department of Climate Change, Energy, the Environment and Water (2024). Australia's emissions projections 2023, 8 October. www.dcceew.gov.au/climate-change/publications/australias-emissions-projections-2023. Accessed 9 October 2024.

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.

Braby, D. (2024). Woodland Statistics. Forest Research. https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/woodland-statistics/. Accessed 22 October 2024.

Brazil, Ministry of Environment and Climate Change (2023). *Taxa de desmatamento na Amazônia cai 22,3% em um ano*, *gob.br*. Brasília. www.gov.br/mma/pt-br/taxa-de-desmatamento-na-amazonia-cai-22-3-em-2023.

Brazil, Ministry of Finance (2024). *Plano de Transformação Ecológica*. Brasília. www.gov.br/fazenda/pt-br/acesso-a-informacao/acoes-e-programas/transformacao-ecologica/pte.

Canada (2023). *2023 Progress Report on the 2030 Emissions Reduction Plan*. Ottawa. www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/2023-progress-report.html.

China, Ministry of Ecology and Environment (2023). *Measures for the Administration of Voluntary Greenhouse Gas Emission Reduction Trading (for Trial Implementation).* Beijing. https://www.gov.cn/zhengce/zhengceku/202310/content_6910691.htm.

China, State Council (2024a). *Interim Regulations on the Administration of Carbon Emission Trading*. Beijing. https://www.gov.cn/zhengce/content/202402/content_6930137.htm.

__________ (2024b). *Notice of the State Council on Printing and Distributing the Action Plan for Energy Conservation and Carbon Reduction from 2024 to 2025.* Beijing. https://www.gov.cn/zhengce/zhengceku/202405/content_6954323.htm.

Clean Development Mechanism Designated National Authority (2022). GCOM STEPS, undated. https://gcom.cdmdna.gov.sa/Overall. Accessed 22 October 2024.

Climate Action Tracker (2024). Countries. Climate Action Tracker. https://climateactiontracker.org/countries/. Accessed 22 October 2024.

Climate Change Committee (2023). *CCC* assessment of recent announcements and developments on Net Zero, 12 October. www.theccc.org.uk/2023/10/12/ccc-assessment-of-recent-announcements-and-developments-on-net-zero/. Accessed 22 October 2024.

COMMIT Consortium (2021). *COMMIT Scenario Explorer (1.1)*. Zenodo. https://doi.org/10.5281/zenodo.5727072.

Council of the European Union (2023). *Fit for 55 package: Council adopts regulations on effort sharing and land use and forestry sector*. 28 March. www.consilium.europa.eu/en/press/press-releases/2023/03/28/fit-for-55-package-council-adopts-regulations-on-effort-sharing-and-land-use-and-forestry-sector/.

European Environment Agency (2023). Member States' greenhouse gas (GHG) emission projections, 24 October. www.eea.europa.eu/en/datahub/datahubitem-view/4b8d94a4-aed7-4e67-a54c-0623a50f48e8. Accessed 9 October 2024.

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(5), 33. https://doi.org/10.1007/ s11027-022-10008-7.

Energy UK (2024). Energy UK explains: Allocation round 6 and the UK's energy security goals, 22 February. www.energy-uk.org.uk/publications/energy-uk-explains-allocation-round-6-and-the-uks-energy-security-goals/. Accessed 22 October 2024.

Environment and Climate Change Canada (2023). Greenhouse gas emissions projections, undated. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections.html. Accessed 9 October 2024.

Espejo, S. and Hilfiker, J. (2020). Pipeline project to relieve Yucatan Peninsula gas shortages, 4 February. www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/020420-pipeline-project-to-relieve-yucatan-peninsula-gas-shortages. Accessed 22 October 2024.

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. https://doi.org/10.1016/j.energy.2020.119385.

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.

Gabbatiss, J. and Viisainen, V. (2024). Analysis: UK misses tree-planting targets by forest the 'size of Birmingham', 26 June. Carbon Brief. www.carbonbrief.org/analysis-uk-misses-tree-planting-targets-by-forest-the-size-of-birmingham/. Accessed 22 October 2024.

Grassi, G., Schwingshackl, C., Gasser, T., Houghton, R.A., Sitch, S., Canadell, J.G. *et al.* (2023). Harmonising the land-use flux estimates of global models and national inventories for 2000–2020. *Earth System Science Data* 15(3), 1093-1114. https://doi.org/10.5194/essd-15-1093-2023.

Haifeng, Q. (2024). *The five departments jointly issued a document to promote energy conservation and carbon reduction in four key industries - accelerate the green transformation of development mode*. 6 October. *www.gov.cn*. https://www.gov.cn/zhengce/202406/content_6956508.htm.

India, Ministry of Power (2023). *National Framework for Promoting Energy Storage Systems*. New Delhi. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/09/202309051208486334.pdf.

Jenkins, J.D., Mayfield, E.N., Farbes, J., Jones, R., Patankar, N., Xu, Q. and Schivley, G. (2022). *Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022*. ZERO LAB, Princeton University. 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.* (2023). *Global Energy and Climate Outlook 2023: Investment Needs in a Decarbonised World*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/836798.

Larsen, J., King, B., Kolus, H., Dasari, N., Bower, G. and Jones, W. (2022). *A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act*. https://rhg.com/research/climate-clean-energy-inflation-reduction-act/. New York, United States: Rhodium Group.

Levin, K. and Rich, D. (2017). *Turning Points: Trends In Countries' Reaching Peak Greenhouse Gas Emissions Over Time*. Washington, DC: World Resources Institute. https://www.wri.org/research/turning-points-trends-countries-reaching-peak-greenhouse-gas-emissions-over-time.

Madry, K. (2023). Mexico Pacific to pump $14 billion into pipeline, plant, 3 May. www.reuters.com/business/energy/mexico-president-sees-14-bln-investment-mexico-pacific-pipeline-liquefaction-2023-05-03/.

Meinshausen, M., Lewis, J., Nicholls, Z.R.J. and Guetschow, J. (2023). NDC Factsheets. Zenodo. https://doi.org/10.5281/zenodo.8010081. Accessed 7 October 2024.

Republic of Korea, Ministry of Environment (2023). *Overview of the National Plan for Carbon Neutrality and Green Growth*. Seoul. https://m.me.go.kr/eng/web/board/read.do?menuId=461&boardMasterId=522&boardId=1591210.

India, Ministry of Jal Shakti and Department of Drinking Water and Sanitation (2023). *Unified Registration Portal for GOBARdhan Plants*, *GOBARdhan*. New Delhi. https://gobardhan.co.in/.

India, Ministry of Petroleum and Natural Gas (2023). *Blending of Bio-fuels*. 11 December. New Delhi. https://pib.gov.in/PressReleasePage.aspx?PRID=1984975.

India, Ministry of New and Renewable Energy and Council on Energy, Environment and Water (2024). *Green Hydrogen Standards and Approval Systems in India: Streamlining the Green Hydrogen Ecosystem for Accelerated Implementation of National Green Hydrogen Mission*. New Delhi. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc2024510336201.pdf.

Mexico, Ministry of Finance and Public Credit (2023a). *Comunicado No. 16 La Secretaría de Hacienda presenta la Taxonomía Sostenible de México*. 12 March. http://www.gob.mx/shcp/prensa/comunciado-no-16-la-secretaria-de-hacienda-presenta-la-taxonomia-sostenible-de-mexico.

__________ (2023b). *Taxonomía Sostenible De México*. Primero edición. Mexico City. https://www.gob.mx/cms/uploads/attachment/file/809773/Taxonom_a_Sostenible_de_M_xico_.pdf.

Nascimento, L., Kuramochi, T., Woollands, S., Moisio, M., Missirliu, A. *et al.* (2023). *Greenhouse Gas Mitigation Scenarios For Major Emitting Countries: Analysis of Current Climate Policies and Mitigation Commitments – 2023 Update*. Germany: NewClimate Institute. https://newclimate.org/sites/default/files/2023-11/NewClimate_PBL2023_CurrentPolicies.pdf.

Nascimento, L., Scheewel, J.-L., Kuramochi, T., Dafnomilis, I., Hooijschuur, E., Forsell, N. *et al.* (2024). Progress of major emitters towards climate targets. NewClimate Institute, PBL Netherlands Environmental Assessment Agency, IIASA International Institute for Applied Systems Analysis. https://newclimate.org/resources/ publications/progress-of-major-emitters-towards-climate-targets-2024-update.

Mexico (2022). *Presidente AMLO inaugura Refinería Dos Bocas "Olmeca": es un sueño convertido en realidad*. Mexico City. http://www.gob.mx/presidencia/prensa/presidente-amlo-inaugura-refineria-dos-bocas-olmeca-es-un-sueno-convertido-en-realidad?idiom=es.

Saudi Arabia, Ministry of Energy (2024). *Saudi Power Procurement Company (SPPC) Signs Power Purchase Agreements for Three New Solar Energy Projects with a Total Capacity of 5,500 MW*. Riyadh. www.moenergy.gov.sa/en/MediaCenter/News/Pages/SPPC-Signs-PPA-for-Three-New-Solar-Energy-Projects-with-5500MW-Capacity.aspx.

Saudi Arabia, Ministry of Finance (2023). *Kingdom of Saudi Arabia Green Financing Framework*. https://ndmc.gov.sa/investorsrelations/Documents/Green-Financing-Framework-KSA-16April2024.pdf.

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.

Sawyer, D., Kanduth, A., Girffin, B., Förg, F., Linden-Fraser, R. and Zhang, A. (2023). *Independent Assessment of Canada's 2023 Emissions Reduction Plan Progress Report*. Ottawa: Canadian Climate Institute. https://climateinstitute.ca/wp-content/uploads/2023/12/ERP-assessment-2023-EN.pdf.

Schmidt Tagomori, I., Dafnomilis, I., Fricko, O., Richters, O., Bertram, C., Drouet, L. *et al.* (2023). ENGAGE Post-Glasgow Long-term Strategies. International Institute for Applied Systems Analysis. https://doi.org/10.5281/zenodo.10009463.

Schmidt Tagomori, I., den Elzen, M., van Vuuren, D., Diuana, F.A. and Schaefer, R. (2023). *Promising Climate Progress.* Laxenburg, Austria: International Institute for Applied Systems Analysis. https://www.engage-climate.org/wp-content/uploads/2023/10/PB34_Engage-policy-briefweb_0.pdf.

Singh, R. (2023). Middle East's clean hydrogen capacity plans double year on year, 25 September. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/092523-middle-easts-clean-hydrogen-capacity-plans-double-year-on-year.

van Soest, H., Reis, L.A., Baptista, L.B., Bertram, C., Després, J., Drouet, L. *et al.* (2021). A global roll-out of nationally relevant policies bridges the emissions gap. *Nature Communications*, 12(6419). https://doi.org/10.1038/s41467-021-26595-z.

European Parliament and the Council of the European Union (2023a). *Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on Energy Efficiency and Amending Regulation (EU) 2023/955 (recast)*. Brussels. https://eur-lex.europa.eu/eli/dir/2023/1791/oj.

__________ (2023b). *Directive (EU) 2023/2413 of the European Parliament and of the council amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as Regards the Promotion of Energy from Renewable Sources, and Repealing Council Directive (EU) 2015/652*. Brussels. https://eur-lex.europa.eu/eli/dir/2023/2413/oj.

United Nations Framework Convention on Climate Change (2023). *NDC Registry*. Bonn, Germany. https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx.

United Kingdom, Department for Energy Security and Net Zero (2023). *Energy and emissions projections: 2021 to 2040. Annex A: National Communication categories: Greenhouse gas emissions by source (revised 10 March 2023)*. London.

United Kingdom, Department for Energy Security and Net Zero and Department for Business and Trade (2023). *Offshore Wind Net Zero Investment Roadmap*. London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1167856/offshore-wind-investment-roadmap.pdf.

United States of America, Environmental Protection Agency (2024a). EPA's Final Rule for Oil and Natural Gas Operations Will Sharply Reduce Methane and Other Harmful Pollution, 2 December. https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-operations/epas-final-rule-oil-and-natural-gas.

__________ (2024b). *Final Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles*, *EPA*. Washington, DC. https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model.

__________ (2024c). *Greenhouse Gas Standards and Guidelines for Fossil Fuel-Fired Power Plants*. Washington, DC. https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power.

## Appendix C

## Supplementary material for Chapter 4 - The emissions gap in 2030 and 2035

### C.1 Current policies scenarios

The **current policies scenario** projects global greenhouse gas (GHG) emissions assuming all currently adopted and implemented policies (defined as legislative decisions, executive orders, or equivalent) are realized and that no additional measures are undertaken. Typically, selected policies are based on literature research, inputs from the Climate Policy Database (NewClimate Institute, 2023) and a country expert review of the policies identified, often following the modelling protocol for the implementation of policies in global models from Roelfsema *et al.* (2020; 2022). The data for this scenario are based on the same four modelling studies of the current policies assessment of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) WG III report (Lecocq *et al.* 2022) (see Table 4.2), but using more recent GHG emissions projections by the same four modelling studies, i.e. Climate Action Tracker, (2023), PBL (den Elzen *et al.* 2024; den Elzen *et al.* 2023; Nascimento *et al.* 2023), JRC- GECO (Keramidas *et al.* 2023) and ENGAGE (Riahi *et al.* 2021; Tagomori *et al.* 2023). These studies provide updated estimates that use a policy cut-off date of November 2023 and apply the most recent AR6 100-year global warming potential (GWP) values. In addition, to these four studies, the GHG emissions projection of the International Energy Agency (IEA) STEPS scenario of the IEA World Energy Outlook 2023 was included (IEA 2023; IEA 2024). The resulting median estimate of global GHG emissions in 2030 and 2035 under current policies for those five studies is 57 $GtCO_2e$ (range: 53–59) and 56 $GtCO_2e$ (range: 50-60), respectively (Figure 4.1). The median 2030 estimate is about 0.5 $GtCO_2e$ higher than the median estimate of the 2023 UNEP Emissions Gap Report, which is mainly due to the impact of updated recent emissions trends and methodological updates. Extending beyond 2030, the Current policies scenario assumes a continuation of efforts at a level of ambition consistent with the reductions by 2030.[1]

### C.2 Updated NDC scenarios

The updated **NDC scenarios** encompass the most recent versions of the unconditional and conditional NDCs submitted by the UNFCCC parties. The estimates are derived using a similar approach as described by Lecocq *et al.* (2022) (table 4.3) and reflect the latest updates available as of September 2024. These updates are based on findings from four modeling exercises conducted by (Climate Action Tracker, 2023), JRC-GECO (Keramidas *et al.* 2023), PBL (den Elzen *et al.* 2023) and Meinshausen *et al.* (2023). The unconditional and conditional NDC scenarios estimates result in a median of global GHG emissions of 55 $GtCO_2e$ (with a range of 54 to 57) and 51 $GtCO_2e$ (and a range of 48 to 55), respectively, which are similar to the median estimates of the 2023 UNEP Emissions Gap Report. Extending beyond 2030, the NDC scenarios assume a continuation of efforts at a level of ambition consistent with the reductions by 2030.

[1] For a technical discussion and details of the method, see Chapter 4 of the 2023 Emissions Gap Report, Appendix C1, available at https://wedocs.unep.org/handle/20.500.11822/44021

## C.3 Mid-century scenario extensions

The **mid-century scenario extensions** aim to explore the longer-term implications of current policies, NDCs and net-zero pledges. This includes long-term low GHG emission development strategies and other long-term pledges announced as of July 2024. Because GHG projections to mid-century are subject to much larger policy uncertainty than projections out to 2030, two cases are presented that span the wide range of potential futures (Rogelj *et al.* 2023). The most conservative case is identical to the current policies scenario in which no long-term net-zero pledges are assumed to be achieved. At the other extreme sits this report's most optimistic scenario, which starts from the conditional NDC scenario and in which all pledged net-zero reduction targets or ambitions are assumed to be achieved.

## C.4 Scenarios for keeping warming below specified temperature limits

The scenarios considered here present least-cost mitigation pathways that lead to different peak global warming outcomes relative to pre-industrial levels over the course of this century. Three scenario categories are defined 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 were drawn from the IPCC AR6 WG III database (Byers *et al.* 2022; Riahi *et al.* 2022) and grouped according to characteristics as described in table 4.1. Their corresponding temperature projections are based on the IPCC AR6 WG I physical science assessment (Kikstra *et al.* 2022; Nicholls *et al.* 2021) and consistent with recent updates to the remaining carbon budget Forster *et al*. (2024). Assessed scenarios start their projections from the year 2020 onwards. New scenarios that update this start year to a more recent year are only just appearing in the literature (Bertram *et al*. 2024) and logically show greater challenges to have a high chance of achieving the deepest warming targets. As this literature develops further, an update of mitigation pathways is anticipated in future editions of this report (see also Box 4.2).

Note that *Below 2°C* and *Below 1.8°C* scenarios keep warming below these limits and only allow for a 1-in-3 chance that warming exceeds these limits throughout the century. In line with definitions applied by the IPCC 1.5°C Special Report (Rogelj *et al*. 2018) and the IPCC AR6 WG III assessment (Riahi *et al*. 2022), *Around 1.5°C* scenarios allow for a larger chance that warming exceeds 1.5°C (a 2-in-3 chance) over the course of the century. This exceedance is assumed be reversed by 2100 when these pathways must result in a 1-in-2 chance of having returned warming below 1.5°C. In the second half of the century, the around 1.5°C pathways also achieve net-zero GHG emissions, which implies that global net negative $CO_2$ emissions are achieved prior to that (Rogelj *et al*. 2021).

**Table C.1.** Global projections for alternative time periods under the policy scenarios assessed in this chapter, and exceedance probabilities for alternative temperature limits.

| Warming in 2050 (°C) | | | |
|---|---|---|---|
| **Scenario** | **66% chance** | **50% chance** | **90% chance** |
| **Current policies continuing** | 2.0 (1.9–2.2) | 1.9 (1.8–2.1) | 2.5 (2.2–2.7) |
| **Unconditional NDCs continuing** | 2.0 (1.9–2.1) | 1.9 (1.8–2.1) | 2.4 (2.2–2.7) |
| **Conditional NDCs continuing** | 1.9 (1.8–2.1) | 1.8 (1.7–2.0) | 2.3 (2.1–2.6) |
| **Conditional NDC + all net-zero pledges** | 1.8 (1.7–2.0) | 1.7 (1.6–1.8) | 2.1 (2.0–2.4) |

| Warming in 2100 (°C) | | | |
|---|---|---|---|
| **Scenario** | **66% chance** | **50% chance** | **90% chance** |
| **Current policies continuing** | 3.0 (1.9–3.8) | 2.8 (1.7–3.5) | 3.6 (2.3–4.5) |
| **Unconditional NDCs continuing** | 2.8 (1.9–3.7) | 2.6 (1.7–3.4) | 3.3 (2.3–4.3) |
| **Conditional NDCs continuing** | 2.5 (1.6–3.6) | 2.3 (1.5–3.3) | 3.0 (2.0–4.2) |
| **Conditional NDC + all net-zero pledges** | 1.9 (1.4–2.3) | 1.7 (1.3–2.1) | 2.2 (1.7–2.8) |

| Likelihood of warming exceeding a specific temperature limit (%) | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **1.5°C** | **2°C** | **2.5°C** | **3°C** | **4°C** |
| **Current policies continuing** | 100 (85–100) | 97 (28–100) | 75 (5–97) | 37 (1–80) | 4 (0–22) |
| **Unconditional NDCs continuing** | 100 (86–100) | 94 (28–100) | 58 (5–96) | 22 (1–75) | 1 (0–19) |
| **Conditional NDCs continuing** | 100 (77–100) | 79 (19–100) | 35 (2–94) | 10 (0–69) | 0 (0–16) |
| **Conditional NDC + all net-zero pledges** | 77 (64–97) | 20 (9–63) | 3 (1–22) | 0 (0–6) | 0 (0–0) |

| Likelihood of warming exceeding a specific temperature limit in the year 2100 (%) | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **1.5°C** | **2°C** | **2.5°C** | **3°C** | **4°C** |
| **Current policies continuing** | 100 (77–100) | 97 (23–100) | 75 (4–97) | 37 (1–80) | 4 (0–22) |
| **Unconditional NDCs continuing** | 100 (78–100) | 94 (24–100) | 58 (5–96) | 22 (1–75) | 1 (0–19) |
| **Conditional NDCs continuing** | 100 (50–100) | 79 (9–100) | 35 (1–94) | 10 (0–69) | 0 (0–16) |
| **Conditional NDC + all net-zero pledges** | 75 (25–97) | 20 (3–63) | 3 (0–22) | 0 (0–6) | 0 (0–0) |

## References


Bertram, C., Brutschin, E., Drouet, L., Luderer, G., van Ruijven, B., Aleluia Reis, L. *et al.* (2024). Feasibility of peak temperature targets in light of institutional constraints. *Nature Climate Change* 14(9), 954-960. https://doi.org/10.1038/s41558-024-02073-4.

Byers, E., Krey, V., Kriegler, E., Riahi, K., Schaeffer, R., Kikstra, J. *et al.* (2022). AR6 Scenarios Database (Version 1.0). Zenodo. https://doi.org/10.5281/zenodo.5886912. Accessed 7 October 2024.

Climate Action Tracker (2023). No change to warming as fossil fuel endgame brings focus onto false solutions, 12 May. https://climateactiontracker.org/publications/no-change-to-warming-as-fossil-fuel-endgame-brings-focus-onto-false-solutions/. Accessed 7 October 2024.

den Elzen, M. (2024). Infographics PBL NDC Tool March 2024 (Version 1). Zenodo. https://zenodo.org/records/10875617. Accessed 7 October 2024.

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(5), 33. https://doi.org/10.1007/s11027-022-10008-7.

Forster, P.M., Smith, C., Walsh, T., Lamb, W.F., Lamboll, R., Hall, M. *et al.* (2024). Indicators of Global Climate Change 2023: Annual update of key indicators of the state of the climate system and human influence. *Earth System Science Data* 16(6), 2625-2658. https://doi.org/10.5194/essd-16-2625-2024.

International Energy Agency (2023). *World Energy Outlook 2023*. International Energy Agency, Paris. France.

__________ (2024). *Personal communication, IEA GHG emissions projection of IEA World Energy Outlook 2023.*

Keramidas, K., Fosse, F., Diaz Rincon, A., Dowling, P., Garaffa, R., Ordonez, J. *et al.* (2023). *Global Energy and Climate Outlook 2023: Investment Needs in a Decarbonised World*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/836798.

Kikstra, J.S., Nicholls, Z.R.J., Smith, C.J., Lewis, J., Lamboll, R.D., Byers, E. *et al.* (2022). The IPCC *Sixth Assessment Report* WGIII climate assessment of mitigation pathways: From emissions to global temperatures. *Geoscientific Model Development* 15(24), 9075-9109. https://doi.org/10.5194/gmd-15-9075-2022.

Lecocq, F., Winkler, H., Daka, J.P., Fu, S., Gerber, J.S., Kartha, S. *et al.* (2022). Mitigation and development pathways in the near to mid-term. 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 4. 409-502. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter04.

pdf.

Meinshausen, M., Lewis, J., Nicholls, Z.R.J. and Guetschow, J. (2023). NDC Factsheets. Zenodo. https://doi.org/10.5281/zenodo.8010081. Accessed 7 October 2024.

Nascimento, L., Kuramochi, T., Woollands, S., Moisio, M., Missirliu, A. *et al.* (2023). *Greenhouse Gas Mitigation Scenarios For Major Emitting Countries: Analysis of Current Climate Policies and Mitigation Commitments – 2023 Update*. Germany: NewClimate Institute. https://newclimate.org/sites/default/files/2023-11/NewClimate_PBL2023_CurrentPolicies.pdf.

NewClimate Institute (2023). *Climate Policy Database*. https://newclimate.org/resources/tools/climate-policy-database. Accessed 22 October 2024.

Nicholls, Z.R.J., Meinshausen, M., Forster, P., Armour, K., Berntsen, T., Collins, W. *et al.* (2021). Physical emulation of Earth System Models for scenario classification and knowledge integration in AR6. 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., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (eds.). Cambridge and New York: Cambridge University Press. Cross-Chapter Box 7.1. 962-967. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf.

Riahi, K., Bertram, C., Huppmann, D., Rogelj, J., Bosetti, V., Cabardos, A.-M. *et al.* (2021). Cost and attainability of meeting stringent climate targets without overshoot. *Nature Climate Change* 11(12), 1063-1069. https://doi.org/10.1038/s41558-021-01215-2.

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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 3. 295-408. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter03.pdf.

Roelfsema, M., van Soest, H.L., den Elzen, M., de Coninck, H., Kuramochi, T., Harmsen, M. *et al.* (2022). Developing scenarios in the context of the Paris Agreement and application in the integrated assessment model IMAGE: A framework for bridging the policy-modelling divide. *Environmental Science & Policy* 135, 104–116. https://doi.org/10.1016/j.envsci.2022.05.001.

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.

Rogelj, J., Fransen, T., den Elzen, M.G.J., 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://www.science.org/doi/10.1126/science.adg6248.

Rogelj, J., Geden, O., Cowie, A. and Reisinger, A. (2021). Net-zero emissions targets are vague: three ways to fix. *Nature* 591(7850), 365–368. https://doi.org/10.1038/d41586-021-00662-3.

Tagomori, I., den Elzen, M., van Vuuren, D., Diuana, F.A. and Schaeffer, R. (2023). *Promising Climate Progress*. Laxenburg, Austria: International Institute for Applied Systems Analysis. http://www.engage-climate.org/wp-content/uploads/2023/10/PB34_Engage-policy-briefweb_0.pdf.

## Appendix D

## Supplementary material for Chapter 5 - Bridging the Gap: Translating global milestones into action and ambition in the next nationally determined contributions of G20 members

### D.1 Methodology for constructing cost-effective and fair-share ambition ranges

The following section provides further information on how the ambition ranges presented for the G20 in the chapter were constructed.

#### 'Fair-share' ranges

Fair-share approaches translate global emission pathways to the national level from the perspective of what could constitute a countries' fair contribution to global emission reductions, without considering whether this is also domestically feasible or requires a component of international support.

The philosophical literature on climate justice suggests different principles to fairly share future emission allowances (Caney 2020). In addition, there are legal interpretations (Rajamani *et al.* 2021) such as the Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) principle in the Paris Agreement. Based on these philosophical and legal considerations of equity, several equity approaches have been developed in the literature.

For example, approaches based on the 'Polluter Pays' principle (also called 'Responsibility') assign a higher share of the reduction effort to countries with a higher historical responsibility for global warming (e.g. measured by their cumulative past greenhouse gas emissions from a certain starting year onwards). Approaches based on the 'Ability to Pay' principle ('Capability') require countries with a higher capability to reduce emissions (as e.g. indicated by the level of a countries' GDP per capita) to carry a higher share. Some approaches also consider a country's right to sustainable development and meeting their basic needs. The CBDR-RC principle in the Paris Agreement acknowledges both the 'Responsibility' and 'Capability' of a country, also sustainable development is recognized in the Paris Agreement. However, there are also equity approaches that have been proposed which are not in line with the CBDR-RC principle and the Paris Agreement, most notably approaches based on cost-effective considerations or grandfathering (i.e., demanding that future emission entitlements are in line with current emission shares) (Kartha *et al.* 2018; Rajamani *et al.* 2021).

Several possible approaches to translating these different equity principles into quantitative greenhouse gas (GHG) estimates for each country have been suggested. The final fair share estimate is therefore not only determined by the equity principles, but also by the quantitative implementation and parametrisation (van den Berg *et al.* 2020). Choices for implementing equity schemes include whether to fairly share the global emissions allowances consistent with limiting warming to the Paris target (Pelz, Rogelj and Riahi 2023) or whether to share the necessary global emissions reductions from a hypothetical reference scenario (Winkler *et al.* 2011; Holz, Kartha and Athanasiou 2018). Other choices include which gases and sectors to consider, which fair share principles to include and which indicators and parameters to use. These choices can have a large impact on the outcome and form value judgements. For example, when measuring the responsibility of a country with its cumulative past emissions, from when does one start to count emissions?

In the absence of a political consensus on fair share principles and implementations and in consideration of the very different allocation results of them, the ambition ranges reflecting the spread of different approaches are provided. Equity pathways from the literature that cover all G20 countries are considered (Baer *et al.* 2008; Höhne and Moltmann 2008; Höhne and Moltmann 2009; Robiou Du Pont *et al.* 2017; Holz, Kartha and Athanasiou 2018). As there is a limited set of literature which provides data for all G20 countries, this data is complimented with implementations of the major equity approaches which are consistent with international environmental law. For each approach, the allowance pathways of all individual G20 members are summed to give an overall G20 pathway that is aligned with a given fair-share approach. The additional implementations that complement the literature cover several parameter combinations and approaches, namely:

- Effort-sharing with indicators reflecting historical responsibility and capability
- South African Proposal
- Greenhouse Development Rights
- Per capita convergence
- Common but differentiated convergence

Taken together, this means that the dataset of approaches used here covers the equity principles of responsibility, capability, responsibility-capability-need, equality, staged approaches and equal cumulative per capita. While some of these approaches are contested in the literature (Kartha *et al.* 2018; Dooley *et al.* 2021), they represent the major approaches which can find their basis in principles of international environmental law (Rajamani *et al.* 2021).

## D.2 Cost-effective ranges

Cost-effective approaches to translating global emission reduction milestones to the national level generally focus on using energy-system and economic models to produce global energy and emissions pathways, and then downscaling these pathways to the national level. This approach is used by a variety of different projects and actors (NGFS 2023; Climate Action Tracker 2023; Climate Analytics 2024).

The starting point for this approach is global energy and emissions pathways consistent with the Paris Agreement goal. Such pathways are predominantly produced by integrated assessment models (IAMs) (Riahi *et al.* 2022). These couple together economic-, energy- and land-use models, and attempt to provide an internally consistent picture of how these coupled systems could evolve in the future. The results of such detailed-process IAMs have been assessed by the IPCC to help inform global emissions reduction milestones, some of which are referenced in chapter 4.

IAMs generally include a range of geophysical and techno-economic constraints in their scenarios, which could for example limit the biomass potential in a region, or the rate of roll-out of wind and solar electricity. The IAMs therefore aim to produce scenarios which are techno-economically feasible. There are however, a broader range of dimensions by which the feasibility of scenarios can be judged, including socio-cultural and institutional dimensions of feasibility (Brutschin *et al.* 2021). While the techno-economic and geophysical feasibility challenges are non-negligible in 1.5ºC compatible pathways, institutional feasibility challenges are some of the most pressing challenges in all Paris-aligned scenarios (IPCC 2022). There is also a growing literature critiquing IAMs and their underlying assumptions (Anderson and Jewell 2019; Gambhir *et al.* 2019), including assumptions made around energy and GDP inequality across countries (Kanitkar, Mythri and Jayaraman 2022).

Detailed-process IAMs are generally utilised for 'cost-effectiveness' analysis (Clarke *et al.* 2014). This sets a pre-determined goal, e.g. limiting warming to 1.5ºC with no or low overshoot, and tries to identify a least-cost pathway towards this. In many models, this is done via intertemporal optimisation, which tries to minimise net present value 'costs' (whether total energy system costs, or consumption losses or another metric) over the time horizon. In other models which do not explicitly conduct intertemporal optimisation, often a predetermined 'economically optimal' carbon price is applied in the model to determine the least-cost pathway.

IAMs therefore distribute regional and sectoral emissions reductions on the basis of where it is assumed to be least-cost, without consideration of equity principles. However, some IAM scenarios are beginning to constrain regional emissions profiles, for example by applying regionally differentiated carbon prices (Baumstark *et al.* 2021), or limiting the pace of the energy transition in certain regions to historically defined precedents (Muttitt *et al.* 2023). While the overall scenario design remains cost-effective analysis, this does inform and influence the regional distribution of emissions reductions within a cost-effective logic.

Most IAMs provide data disaggregated to the level of macro-regions, such as Central and Latin America, or the Middle East and North Africa region. This regional-level data can then be downscaled to the country level.

A range of approaches can be taken to downscaling, including emissions intensity convergence approaches (van Vuuren *et al.* 2007; Gidden *et al.* 2019), fixed ratio approaches (in which a country represents a fixed share of the macro-region's emissions throughout the scenario time-horizon, with this share set by historical data), and economic approaches which estimate a cost-effective distribution of energy consumption and emissions within a region (Sferra *et al.* 2019), mirroring the cost-effective logic of the initial IAM scenario. In all approaches, the exact translation of the global goals into the national level is influenced by:

A) The countries' current context. All downscaling methods start from the current context of the country, in terms of energy consumption, emissions, GDP and more. Some downscaling approaches also capture other key elements of country context, such as current mitigation targets, national-level data such as resource availability and cost-effective mitigation potentials.
B) The behaviour of the macro-region within the global pathway being downscaled. Here the general focus on techno-economically feasible and cost-effective pathways at the global level strongly influences the shape and form of these pathways, and hence the national results.

In the cost-effective ambition ranges presented in this chapter for the G20, results were produced using an emissions intensity convergence approach. The emissions intensity (emissions excluding LULUCF / GDP) is calculated for each country in the base-year (in this case 2019 is taken), and for each macro-region as a whole. The approach then assumes that the emissions intensity in each country in the macro-region will converge exponentially from current levels to the regional average by 2100. Taken alongside future GDP estimates for each country taken from the underlying SSPs, this defines the emissions trajectory for each country. Individual country-level pathways are produced for each G20 member, and then aggregated to provide data for the bloc as a whole.

## References


Anderson, K. and Jewell, J. (2019). Climate policy models debated: wrong tool for the job: debating the bedrock of climate-change mitigaton scenarios and clarifying the job of IAMs. *Nature* 573(7774), 348–349. https://doi.org/10.1038/d41586-019-02744-9.

Baer, P., Athanasiou, T., Kartha, S. and Kemp-Benedict, E. (2008). *The Greenhouse Development Rights Framework: The Right to Development in a Climate Constrained World*. Berlin: Heinrich-Böll Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute. https://www.sei.org/publications/right-development-climate-constrained-world-greenhouse-development-rights-framework.

Baumstark, L., Bauer, N., Benke, F., Bertram, C., Bi, S., Gong, C.C. *et al.* (2021). REMIND2.1: transformation and innovation dynamics of the energy-economic system within climate and sustainability limits. *Geoscientific Model Development* 14, 6571–603. https://doi.org/10.5194/gmd-14-6571-2021.

Brutschin, E., Pianta, S., Tavoni, M., Riahi, K., Bosetti, V., Marangoni, G. and Van Ruijven, B.J. (2021). A multidimensional feasibility evaluation of low-carbon scenarios. *Environmental Research Letters* 16(6). https://doi.org/10.1088/1748-9326/abf0ce.

Caney, S. (2021). Climate justice, 4 June. https://plato.stanford.edu/archives/win2021/entries/justice-climate/. Accessed 10 October 2024.

Clarke, L., Jiang, K., Akimoto, K., Babiker, M., Blanford, G., Fisher-Vanden, K. *et al.* (2014). Assessing transformation pathways. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Chen, W. and Weyant, J. (eds). Cambridge, UK and New York, USA: Cambridge University Press. Chapter 6. 413–510. www.ipcc.ch/report/ar5/wg3/.

Climate Action Tracker (2023). Modelled domestic pathways, undated. https://climateactiontracker.org/methodology/cat-rating-methodology/modelled-domestic-pathways/. Accessed 10 October 2024.

Climate Analytics (2024). 1.5°C national pathway explorer: methodology, undated. https://1p5ndc-pathways.climateanalytics.org/methodology. Accessed 22 October 2024.

Dooley, K., Holz, C., Kartha, S., Klinsky, S., Roberts, J.T., Shue, H. *et al.* (2021). Ethical choices behind quantifications of fair contributions under the Paris Agreement. *Nature Climate Change* 11(4), 300-305. https://doi.org/10.1038/s41558-021-01015-8.

Gambhir, A., Butnar, I., Li, P.H., Smith, P. and Strachan, N. (2019). A review of criticisms of integrated assessment models and proposed approaches to address these, through the lens of BECCS. *Energies* 12(9), 1747. https://doi.org/10.3390/en12091747.

Gidden, M.J., Riahi, K., Smith, S.J., Fujimori, S., Luderer, G., Kriegler, E. *et al.* (2019). Global emissions pathways under different socioeconomic scenarios for use in CMIP6: A dataset of harmonized emissions trajectories through the end of the century. *Geoscientific Model Development* 12, 1443–1475. https://doi.org/10.5194/gmd-12-1443-2019.

Höhne, N. and Moltmann, S. (2008). *Distribution of Emission Allowances Under the Greenhouse Development Rights and Other Effort Sharing Approaches*. Cologne: Heinrich-Böll-Stiftung. https://www.boell.de/en/publications/resource-governance-ecology-5430.html.

__________ (2009). *Sharing the Effort Under a Global Carbon Budget*. Cologne: Ecofys Germany GmbH. https://awsassets.panda.org/downloads/wwf_ecofys_carbon_budget_final.pdf.

Holz, C., Kartha, S. and Athanasiou, T. (2018). Fairly sharing 1.5: National fair shares of a 1.5°C-compliant global mitigation effort. *International Environmental Agreements: Politics, Law and Economics* 18(1), 117-134. https://doi.org/10.1007/s10784-017-9371-z.

Intergovernmental Panel on Climate Change (2022). *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. www.ipcc.ch/report/ar6/wg3.

Kanitkar, T., Mythri, A. and Jayaraman, T. (2024). Equity assessment of global mitigation pathways in the IPCC Sixth Assessment Report. *Climate Policy* 24(8),1129–1148. https://doi.org/10.1080/14693062.2024.2319029.

Kartha, S., Athanasiou, T., Caney, S., Cripps, E., Dooley, K., Dubash, N.K. *et al.* (2018). Cascading biases against poorer countries. *Nature Climate Change* 8(5), 348-349. https://doi.org/10.1038/s41558-018-0152-7.

Muttitt, G., Price, J., Pye, S. and Welsby, D. (2023). Socio-political feasibility of coal power phase-out and its role in mitigation pathways. *Nature Climate Change* 13, 140-147. https://doi.org/10.1038/s41558-022-01576-2.

Network for Greening the Financial System (2023). *NGFS Climate Scenarios for Central Banks and Supervisors - Phase IV*. Paris: Banque de France. https://www.ngfs.net/en/ngfs-climate-scenarios-phase-iv-november-2023.

Pelz S., Rogelj, J. and Riahi, K. (2023). *Evaluating Equity in European Climate Change Mitigation Pathways for the EU Scientific Advisory Board on Climate Change*. Laxenburg, Austria: International Institute for Applied Systems Analysis. https://pure.iiasa.ac.at/id/eprint/18830/.

Rajamani, L., Jeffery, L., Höhne, N., Hans, F., Glass, A., Ganti, G. *et al.* (2021). National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law. *Climate Policy* 21(8), 983-1004. https://doi.org/10.1080/14693062.2021.1970504.

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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 3. 295-408. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter03.pdf.

Sferra, F., Krapp, M., Roming, N., Schaeffer, M., Malik, A., Hare, B. and Brecha, R. (2019). Towards optimal 1.5° and 2°C emission pathways for individual countries: A Finland case study. *Energy Policy* 133, 110705. https://doi.org/10.1016/j.enpol.2019.04.020.

van den Berg, N.J., van Soest, H.L., Hof, A.F., den Elzen, M.G.J., van Vuuren, D.P., Chen, W. *et al.* (2020). Implications of various effort-sharing approaches for national carbon budgets and emission pathways. *Climatic Change* 162, 1805-1822. https://doi.org/10.1007/s10584-019-02368-y.

van Vuuren, D.P., Lucas, P.L. and Hilderink, H. (2007). Downscaling drivers of global environmental change: Enabling use of global SRES scenarios at the national and grid levels. *Global Environmental Change* 17, 114–130. https://doi.org/10.1016/j.gloenvcha.2006.04.004.

Winkler, H., Letete, T. and Marquard, A. (2011). A South African approach – responsibility, capability and sustainable development. In *Equitable Access to Sustainable Development: Contribution to the Body of Scientific Knowledge*. Beijing, Brasília, Cape Town and Mumbai, India: BASIC expert group. http://gdrights.org/wp-content/uploads/2011/12/EASD-final.pdf.

## Appendix E

## Supplementary material for Chapter 6 - Bridging the gap: Sectoral transformation benchmarks, mitigation potentials and investment needs

### E.1 Global sectoral benchmarks for 2030 and 2035 aligned with 1.5°C pathways.

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 being overly precise.

**Table E.1** Global sectoral benchmarks for 2030 and 2035 aligned with 1.5°C pathways

| Indicator | Benchmark Source | 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 Historical Data Point |
| *Power* | | | | | | |
| **Share of zero-carbon sources in electricity generation (%)** | (BloombergNEF 2024) | 40 (2023) | 69 | +73% | 84 | +110% |
| | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 39 (2023)[a] | 88-91 | +125-133% | 96 | +150% |
| | (International Energy Agency [IEA] 2023a) | 39 (2022) | 71 | +82% | 91 | +130% |
| | (IPCC 2022)[b] | 37 (2019) | 65 | +76% | 77 | +110% |
| | (IRENA 2023)[c] | 39 (2020) | 76 | +95% | N/A | N/A |
| **Renewable power capacity (TW)** | (Grant *et al.* 2024) | 3.4-3.6 (2022) | 12 | +233-253% | 18 | +400-430% |
| | (IEA 2023c) | 3.6 (2022) | 11 | +210% | 18 | +400% |
| | (IRENA 2024) | 3.9 (2023) | 11 | +180% | N/A | N/A |
| **Share of wind and solar in electricity generation (%)** | (BloombergNEF 2024) | 14 (2023) | 43 | +210% | 59 | +320% |
| | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 13 (2023)[a] | 57-78 | +340-500% | 68-86 | +420-560% |
| | (IRENA 2023) | 9 (2020) | 46 | +410% | N/A | N/A |
| **Share of unabated coal in electricity generation (%)** | (BloombergNEF 2024) | 34 (2023) | 7 | -79% | 1 | -97% |
| | (Boehm *et al.* 2023; Schumer *et al.* 2024)[d] | 35 (2023)[a] | 4 | -89% | 1 | -97% |
| | (IEA 2023a) | 36 (2022) | 13 | -64% | 3 | -92% |
| | (IPCC 2022)[b] | 35 (2020) | 3 | -91% | 0 | -100% |
| | (IRENA 2023)[c] | 36 (2020) | 11 | -69% | N/A | N/A |
| **Share of unabated fossil gas in electricity generation (%)** | (BloombergNEF 2024) | 24 (2023) | 11 | -54% | 2 | -92% |
| | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 23 (2023)[a] | 5-7 | -69-78% | 2 | -91% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (IEA 2023a) | 22 (2022) | 16 | -27% | 6 | -73% |
| | (IPCC 2022)[b] | 24 (2020) | 15 | -38% | 7 | -71% |
| | (IRENA 2023)[c] | 22 (2020) | 14 | -36% | N/A | N/A |
| **Carbon intensity of electricity generation (g$CO_2$/kWh)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 480 (2023)[a] | 48-80 | -83-90% | 15-19 | -96-97% |
| **Share of unabated fossil fuels in total energy supply (%)** | (IEA 2023c) | 79 (2022) | 62 | -22% | 57 | -28% |
| | (IPCC 2022)[b] | 83 (2020) | 63 | -24% | 50 | -40% |
| *Industry* | | | | | | |
| **Share of electricity in the industry sector's final energy demand (%)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 29 (2022)[a] | 35-43 | +21-48% | 43-46 | +48-59% |
| **Carbon intensity of global cement production (kg$CO_2$/t cement)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 660 (2020)[a] | 360-370 | -44-45% | N/A | N/A |
| | (IEA 2023b) | 580 (2022) | 450 | -22% | N/A | N/A |
| | (Mission Possible Partnership 2023)[c] | 620 (2022) | 600 | -3.2% | 490 | -21% |
| **Cement production (Mt)** | (IEA 2023a) | 4,200 (2022) | 4,300 | *Production increases expected to meet continued growth in demand.* | 4,100 | -2.4% |
| **$CO_2$ captured in cement production (Mt$CO_2$/yr)** | (IEA 2023a) | 0 (2022) | 170 | >+1,000% | 480 | >+1,000% |
| **Clinker-to-cement ratio (ton per ton)** | (IEA 2023a) | 0.71:1 (2022) | 0.65:1 | -8.5% | 0.61:1 | -14% |
| **Kiln thermal energy intensity (GJ per tonne of clinker)** | (IEA 2023a) | 3.6 (2022) | 3.4 | -5.6% | 3.3 | -8.3% |
| **Share of near-zero emissions clinker in total clinker production (%)** | (IEA 2023a) | 0 (2022) | 8 | >+1,000% | 27 | >+1,000% |
| **Carbon intensity of global steel production (kg$CO_2$/t crude steel)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 1,900 (2023)[a] | 1,340 – 1,350 | -29-30% | N/A | N/A |
| | (IEA 2023b) | 1,400 (2022) | 1,070 | -24% | N/A | N/A |
| | (Mission Possible Partnership 2022a)[c] | 1,500 (2021) | 960 | -36% | 590 | -61% |
| **Crude steel production (Mt)** | (IEA 2023a) | 1,900 (2022) | 2,000 | +5.3% | 2,000 | +5.3% |
| **Near-zero emissions primary steel production (Mt)** | (Mission Possible Partnership 2022b) | N/A | 170 | Insufficient data | N/A | N/A |
| **Share of near-zero emissions iron production in total iron production (%)** | (IEA 2023a) | 0 (2022) | 8 | >+1,000% | 27 | >+1,000% |
| **Net electricity consumption from steel production (EJ/yr)** | (Mission Possible Partnership 2022a) | N/A | 1.1-2.1 | Insufficient data | N/A | N/A |
| **Share of scrap in metallic inputs (%)** | (IEA 2023a) | 33 (2022) | 38 | +15% | 40 | +21% |
| **$CO_2$ captured in steel production (Mt$CO_2$/yr)** | (IEA 2023a) | 1 (2022) | 27 | +260% | 131 | >+1,000% |
| **Green hydrogen production (Mt)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 0.027 (2021) | 58[e] | >+1,000% | N/A | N/A |
| **Low-emissions hydrogen demand in the steel sector (Mt)** | (IEA 2023a) | 0 (2022) | 6 | >+1,000% | 17 | >+1,000% |
| *Agriculture, forestry, and other land uses* | | | | | | |
| **Deforestation (Mha/yr)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 5.4 (2023)[a] | 1.9 | -65% | 1.5 | -72% |
| | (FAO 2023) | N/A | N/A | N/A | 0 | Insufficient Data |
| **Peatland degradation (Mha/yr)** | (Boehm *et al.* 2023; *et al.* 2024) | 0.06 (annual average, 1993–2018) | 0 | -100% | 0 | -100% |
| **Mangrove loss (ha/yr)** | (Boehm *et al.* 2023; *et al.* 2024) | 32,000 (annual | 4,900 | -85% | 4,900 | -85% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | average, 2017–2019)[f] | | | | |
| **Avoided loss of forests and wetlands (total Mha)** | (Wolosin *et al.* 2022) | N/A | 45 Mha | Insufficient data | N/A | N/A |
| **Percentage of terrestrial, freshwater, and marine ecosystems that are protected (%)** | (Wolosin *et al.* 2022) | 17[g] | 30 | +76% | N/A | N/A |
| **Reforestation (total Mha)** | (Boehm *et al.* 2023; *et al.* 2024) | 130 (total gain, 2000-2020) | 100 (2020-2030)[h] | +77% | 150 (2020-2035)[h] | +115% |
| **Peatland restoration (total Mha)** | (Boehm *et al.* 2023; *et al.* 2024) | 0 (as of 2015)[i] | 15 (2020-2030)[h] | >+1,000% | 16 (2020-2035)[h] | >+1,000% |
| | (Wolosin *et al.* 2022) | N/A | 15 (2020-2030)[h] | Insufficient data | N/A | N/A |
| **Mangrove restoration (total ha)** | (Boehm *et al.* 2023; *et al.* 2024) | 15,000 (total direct gain, 1999-2019)[j] | 240,000 (2020-2030)[h] | >+1,000% | N/A | N/A |
| **Adoption of climate-smart forestry across timber-producing natural forests (total Bha)** | (Wolosin *et al.* 2022) | N/A | 1.3 | Insufficient data | N/A | N/A |
| **GHG emissions intensity of agriculture ($gCO_2e$/1,000 kcal)** | (Boehm *et al.* 2023; *et al.* 2024) | 690 (2021)[a] | 500 | -28% | 450 | -35% |
| **GHG emissions of agrifood systems ($GtCO_2e$ per year)** | (FAO 2023) | 16 (2021) | Insufficient data[k] | Gross GHG emissions of agrifood systems cut by 25%. | Agrifood systems are $CO_2$ neutral, only other GHG are net emitters. | Insufficient data |
| **Livestock methane emissions ($GtCO_2e$/yr)** | (FAO 2023) | 3.1 (2021) | 2.3[l] | -25% | N/A | N/A |
| **Crop yields (t/ha)** | (Boehm *et al.* 2023; *et al.* 2024) | 6.7 (2022)[a] | 7.8 | +16% | 8.2 | +22% |
| **Total factor productivity for crops globally (productivity index 100 = 1990)** | (FAO 2023) | 160 (2021) | 180 | +13% | 190 | +19% |
| **Total factor productivity for crops in low-income countries (productivity index 100 = 1990)** | (FAO 2023) | 120 (2021) | 130 | +8% | 130 | +8% |
| **Ruminant meat productivity (kg/ha)** | (Boehm *et al.* 2023; *et al.* 2024) | 29 (2022)[a] | 33 | +14% | 35 | +21% |
| **Adoption of climate-smart management across working lands (total Bha)** | (Wolosin *et al.* 2022) | N/A | 2 | Insufficient data | N/A | N/A |
| **Share of food production lost (%)** | (Boehm *et al.* 2023; *et al.* 2024) | 13 (2021) | 6.5 | -50% | 6.5 | -50% |
| **Food waste (kg/capita)** | (Boehm *et al.* 2023; *et al.* 2024) | 130 (2022)[a] | 61 | -53% | 61 | -53% |
| | (FAO 2023) | N/A | 61[m] | Insufficient data | N/A | N/A |
| **Reduction in food loss and waste (%)** | (Falk *et al.* 2020) | N/A | 25% | Insufficient data | N/A | N/A |
| **Ruminant meat consumption in high-consuming regions (kcal/capita/day)** | (Boehm *et al.* 2023; *et al.* 2024) | 100 (2022)[a] | 79[n] | -21% | 74[n] | -26% |
| **Share of the global population that adopts a healthy plant-based diet (%)** | (Falk *et al.* 2020) | N/A | 40% | Insufficient data | N/A | N/A |
| *Transport* | | | | | | |
| **Number of kilometers of rapid transit per 1 million inhabitants (km/1M inhabitants)** | (Boehm *et al.* 2023; *et al.* 2024) | 20 (2021)[a] | 38 | +90% | N/A | N/A |
| **Number of kilometers of high-quality bike lanes per 1,000 inhabitants (km/1,000 inhabitants)** | (Boehm *et al.* 2023; *et al.* 2024) | 0.0044 (2020) | 2 | +450% | N/A | N/A |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Share of kilometers traveled by passenger cars (% of passenger-km)** | (Boehm *et al.* 2023; *et al.* 2024) | 45 (2019)[o] | 35-43[o] | -4-22% | N/A | N/A |
| **Share of electric vehicles in light-duty vehicle (car and van) sales (%)** | (Boehm *et al.* 2023; Schumer*et al.* 2024)[p] | 12 (2023)[a] | 75-95 | +530-690% | 100 | +730% |
| | (IEA 2023a)[q] | 13 (2022) | 67 | +420% | 100 | +670% |
| | (IEA 2024b)[r] | 16 (2023) | 66 | +270% | 98 | +440% |
| **Share of electric vehicles in the light-duty vehicle (car and van) fleet (%)** | (Boehm *et al.* 2023; Schumer *et al.* 2024)[p] | 2.2 (2023)[a] | 20-40 | +810->1,000% | N/A | N/A |
| **Share of electric vehicles in two- and three-wheeler sales (%)** | (Boehm *et al.* | 47 (2023)[s] | 85 | +81% | N/A | N/A |
| | (IEA 2023a) | 16 (2022) | 78 | +390% | 100 | +530% |
| | (IEA 2024b) | 13 (2023)[s] | 78 | +500% | 100 | +670% |
| **Share of battery electric vehicles and fuel cell electric vehicles in bus sales (%)** | (Boehm *et al.* | 3.1 (2023)[a] | 60 | >+1,000% | N/A | N/A |
| | (IEA 2023a) | 4 (2022) | 56 | >+1,000% | 90 | >+1,000% |
| | (IEA 2024b) | 3.1 (2023) | 54 | >+1,000% | 86 | >+1,000% |
| **Share of electric vehicles in medium and heavy-duty commercial trucks (%)** | (Boehm *et al.* [t] | 1 (2023)[a] | 30 | >+1,000% | N/A | N/A |
| | (IEA 2023a)[t] | 1 (2022) | 37 | >+1,000% | 65 | >+1,000% |
| **Share of sustainable aviation fuels in global aviation fuel supply (%)** | (Boehm *et al.* 2023; Schumer*et al.* 2024) | 0.1 (2022) | 13 | >+1,000% | 28-32 | >+1,000% |
| **Share of zero-emissions fuels in maritime shipping fuel supply (%)** | (Boehm *et al.* 2023; Schumer *et al.* 2024) | 0 (2018) | 5 | >+1,000% | N/A | N/A |
| *Buildings* | | | | | | |
| **Energy intensity of building operations (kWh/m²)** | (Boehm *et al.* 2023; *et al.* 2024) | 150 (2022)[a] | 85-120 | -17-41% | N/A | N/A |
| | (IEA 2023b) | 150 (2022) | 96 | -34% | N/A | N/A |
| **Carbon intensity of building operations (kgCO2/m²)** | (Boehm *et al.* 2023; *et al.* 2024) | 38 (2022) | 13-16 | -58-66% | N/A | N/A |
| | IEA 2023b) | 38 (2022) | 15[u] | -61% | N/A | N/A |
| **Retrofitting rate of buildings (%/yr)** | (Boehm *et al.* 2023; *et al.* 2024) | <1 (2019) | 2.5-3.5 | >+1.5-2.5% | 2.5-3.5 | >+1.5-2.5% |
| | (IEA 2023a) | <1 (2019) | 2.5 | >+1.5% | 2.5 | >+1.5% |
| **Share of new buildings that are zero-carbon in operation (%)** | (Boehm *et al.* 2023; *et al.* 2024) | 5 (2020) | 100 | +19% | 100 | +19% |
| | (IEA 2023a) | 5 (2020) | 100 | +19% | 100 | +19% |
| *Novel carbon dioxide removal* | | | | | | |
| **Novel carbon dioxide removal ($MtCO_2$/yr)** | (Boehm *et al.* 2023; *et al.* 2024) | 0.57 (2022) | 30-690 | >+1,000% | 150-1,700 | >+1,000% |
| | (IEA 2023a) | 1 (2022) | 230[v] | >+1,000% | 630[v] | >+1,000% |
| | (IPCC 2022)[w] | N/A | 330[x] | Insufficient data | 970[x] | Insufficient data |
| | (IRENA 2023) | 2 (2022) | 800[y] | >+1,000% | N/A | N/A |
| | (Smith *et al.* eds. 2024) | 1.3 (2023) | 180-470 | >+1,000% | 530-1,400 | >+1,000% |
| *Cross-cutting* | | | | | | |
| **Global fossil fuel supply for all energy and non-energy uses (EJ)** | (IEA 2023a) | 510 (2022) | 360 | -29% | 240 | -53% |
| | (IPCC 2022)[b] | 480 (2019) | 330 | -30% | 280 | -42% |

*Notes*
[a] The most recent historical data point has been updated, using the same data provider as cited in (Boehm *et al.* 2023).
[b] These benchmarks represent the median values in 2030 and 2035 from all C1 scenarios assessed in (IPCC 2022), as derived by (Achakulwisut *et al.* 2023).
[c] These benchmarks were extracted from graphical charts in each source and, therefore, are approximate.
[d] The indicator presented in (Boehm *et al.* 2023; Schumer *et al.* 2024) focuses on the share of all coal in electricity generation, rather than the share of unabated coal alone.
[e] This benchmark refers to what is needed for the whole economy to decarbonize, rather than the industry sector alone.
[f] (Murray *et al.* 2022) estimated gross mangrove losses from 1999 to 2019 in three-year epochs. To determine the average annual rate of loss, loss for each epoch was divided by the number of years in the epoch.
[g] Historical data on protected areas are limited to land and inland waters only.
[h] 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.
[i] Benchmarks for peatland restoration were derived from (Roe *et al.* 2021) and (Humpenöder *et al.* 2020), which assume that 0 Mha of peatlands globally were rewetted as of 2015. This assumption, however, does not suggest that peatland restoration has not occurred, as there is evidence of rewetting, for example, in Canada, Indonesia, and the Russian Federation (UNEP 2022; Sirin 2022; Badan Restorasi Gambut dan Mangrove Republik Indonesia 2023), but rather speaks to the lack of global data on peatland restoration.

[j] (Murray *et al.* 2022) estimated that a gross area of 180,000 ha of mangrove gain occurred from 1999 to 2019, only 8 percent of which can be attributed to direct human activities, such as mangrove restoration or planting. The most recent data point for mangrove restoration was estimated by taking 8 percent of the total mangrove gain from 1999 to 2019.
[k] (FAO 2023) does not specify a baseline year, so therefore, it is not possible to calculate an absolute value.
[l] (FAO 2023)'s milestone calls for a 25 percent reduction in methane emissions from livestock by 2030, relative to 2020 levels. The 2020 value for livestock methane emissions was taken from FAOSTAT.
[m] (FAO 2023)'s milestone entails reducing per capita food waste at the retail and consumer levels by 50 percent by 2030. This reduction is assumed to be relative to 2019, a commonly used baseline from (UNEP 2021).
[n] 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.
[o] This indicator was calculated using the share of passenger-kilometers traveled in light-duty vehicles.
[p] The historical data and benchmarks for this indicator monitor progress in battery electric vehicle sales for light-duty cars and vans.
[q] The historical data and benchmarks for this indicator monitor progress in battery electric, plug-in hybrid electric, and fuel cell electric vehicle sales for light-duty cars and vans.
[r] The historical data and benchmarks for this indicator monitor progress in battery electric and plug-in hybrid electric vehicle sales for light-duty cars and vans.
[s] The discrepancy in historical data between the BNEF data used by (Boehm *et al.* 2023) and the data published by (IEA 2024b) stems from a difference in definitional scope. IEA defines two-wheelers as vehicles with a top speed of at least 25 kilometers per hour 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 BNEF data incorporated into (Boehm *et al.* 2023) include lower-speed electric mopeds and scooters.
[t] The historical data and benchmarks for this indicator monitor progress in battery electric, plug-in hybrid electric, and fuel cell electric vehicle sales for medium and heavy-duty commercial trucks.
[u] This benchmark was calculated using 2030 GHG emissions and floor area.
[v] These benchmarks exclusively consider DACCS and BECCS, and their scope is limited to only energy sector $CO_2$ emissions.
[w] These benchmarks represent the median values in 2030 and 2035 from all C1 scenarios assessed in (IPCC 2022).
[x] These benchmarks consider DACCS, BECCS, enhanced rock weathering, and biochar.
[y] This benchmark exclusively focuses on BECCS, and its scope is limited to only energy sector $CO_2$ emissions.

Note: Bloomberg is not a validated source.

## E.2 Detailed calculations and references for the industry baseline and potentials

The following tables details all the key numeric 2022 intensity and output, material efficiency, recycling, energy efficiency, fuel switching and CCUS assumptions need to sequentially prepare the mitigation estimates by sector.

**Table E.2** Overview of key assumed values for each industrial sector.

| **Iron and steel** | | |
|---|---|---|
| | **Value** | **Source** |
| 2022 $CO_2e$ intensity per tonne | 1.91 | (WorldSteel Association 2023) |
| 2022 output in tonnes | 1879 | (WorldSteel Association 2023) |
| %/yr material efficiency improvement | 0.68 | Based on 29% over 50 years (IEA 2020) |
| %/yr recycling improvement | 1.25 | (Bataille *et al.* 2021; 2024) |
| %/yr energy efficiency improvement | 1.00 | (Bashmakov *et al.* 2022) |
| %/yr fuel switching | 1.00 | Based on extrapolation of coal to NG switching in (Bataille *et al.* 2024) |
| Production decarbonization and CCS/CCU | See text | This is based on the literature review in (Bataille *et al.* 2024) on the capacity to switch BFBOFs for DRI with CCS and 100% hydrogen DRI. In AR6 all \$50-100/t $CO_{2e}$. Now cost allocated half to 50-100 and half to 100-200 based on DRI with CCS vs 100% hydrogen DRI. Recent modelling shows DRI+CC dominates the first round of investments, roughly 100 Mt. With the right policy these could be convertible (Bataille *et al.* 2024). |

| Cement and concrete | | |
|---|---|---|
| | **Value** | **Source** |
| 2022 kg $CO_{2e}$ intensity per kg cement | 0.639 | 900kg $CO_2$ (~300 heat, ~600 process) per tonne clinker at 71% clinker share per kg cement |
| 2022 clinker output in Mt | 4100 | (IEA 2023b) |
| %/yr material efficiency improvement | 0.60 | Based on 26% over 50 years (IEA 2020) |
| %/yr clinker ratio (LC3 cements) | 1.40 | Based on LC3 cements used to reach a 50:50 clinker ratio (LC3 2024)https://lc3.ch/ |
| %/yr energy efficiency improvement | 1.00 | (Bashmakov *et al.* 2022) |
| %/yr fuel switching | 1.00 | Based on extrapolation of coal to NG & waste switching (Bashmakov *et al.* 2022) |
| Production decarbonization and CCS/CCU | | Process change or 90% CCUS retrofit/rebuild (33% by 2040, 66% by 2050) |
| **Chemicals** | | |
| | **Value** | **Source** |
| 2022 kg $CO_{2e}$ intensity per tonne chemicals | 2.06 | (IEA 2020) |
| 2019 output ammonia, methanol and HVCs | 680 | (IEA 2020) |
| %/yr material efficiency improvement | 0.60 | Based on 25% over 50 years (IEA 2020) |
| %/yr enhanced recycling | 0.9 | <5% today, increased to 20% of markets share by 2050 |
| %/yr energy efficiency improvement | 1.00 | (Bashmakov *et al.* 2022) |
| %/yr fuel switching | 1.00 | Based on extrapolation of coal to NG, direct electrification & heat pumps, and district heat sharing /cascading (Bashmakov *et al.* 2022) |
| Production decarbonization and CCS/CCU | | CCUS, clean H2, biocarbon, electric crackers (33% by 2040, 66% by 2050.) |
| Notes: | | Future assessments should separate ammonia, methanol, olefins (aka high value chemicals) and other, as their growth rates and intensities are dissimilar. |
| **Aluminum** | | |
| | **Value** | **Source** |
| 2022 kg $CO_{2e}$ intensity per kg aluminum | 2.6 | kg GHGs per kg aluminum not including Scope 2 electricity. 0.8 PFC, 1.5 cathode (IEA 2020) |
| 2022 output aluminum Mt | 68.5 | (IEA 2020) |
| %/yr material efficiency improvement | 1.0 | Based on 25% over 30 years (IEA 2020) |
| %/yr enhanced recycling | 1.2 | 25% today, increased by 25% of markets share by 2050 |
| %/yr energy efficiency improvement | 1.0 | (Bashmakov *et al.* 2022) |
| %/yr fuel switching | 0 | |
| Production decarbonization and CCS/CCU | | zero GHG electricity and inert electrodes; 33% remainder by 2040, 66% by 2050. |
| **Pulp and Paper** | | |

| | Value | Source |
|---|---|---|
| 2022 $CO_{2e}$ intensity | N/A | |
| 2022 output | NA | |
| Bioenergy and clean electrification | | 141 Mt per year by 2035 |
| Production decarbonization and CCS/CCU/CDR | | 282 Mt or more by 2050 |
| **Other Industry** | | |
| | **Value** | **Source** |
| 2022 $CO_{2e}$ intensity | N/A | |
| 2022 output | N/A | |
| 2022 $CO_2$ emissions | | 10320 Mt $CO_2$ grown at -3.1%, 6.1% & 2.5% per year 2019->2020, 2020-> 2021, 2021->2022 |
| %/yr material efficiency improvement | 0.5 | Based on 12.5% over 30 years |
| %/yr enhanced recycling | N/A | |
| %/yr energy efficiency improvement | 1.00 | (Bashmakov *et al.* 2022) |
| %/yr fuel switching | 2.5 | Based on coal to NG to direct electrification (Bashmakov *et al.* 2022) |
| Production decarbonization and CCS/CCU | | Other fuel switching (e.g. bio or synth methane, 25, 50 and 75% of remainder) |

## **Table E.3** Global mitigation potentials across sectors in 2030 and 2035

Estimates represent annual potentials ($GtCO_2e$/yr) available under USD 200/$tCO_2$; with uncertainty ranges in parentheses. The aggregated estimates are corrected to reduce potential overlaps. Industry estimates are corrected for autonomous energy efficiency improvements. A detailed methodology on the aggregate estimates, as well as the calculations for each measure is provided in a separate study (Smit *et al.* 2024). Please note that there is a small difference in the sum of the aggregated sectoral potentials (including the correction for overlap) and the total mitigation potential due to rounding.

| **Mitigation potential ($GtCO_{2e}$)** | **EGR 2017** | **IPCC AR6** | **EGR 2024** | | **Source** |
|---|---|---|---|---|---|
| | **2030** | **2030** | **2030** | **2035** | |
| ***Cost cut-off (\$/$tCO_2$e)*** | *100* | *100* | *200* | *200* | |
| **Total mitigation potential** | **38** *(35 – 41)* | **38** *(32 – 44)* | **31** *(25 - 35)* | **41** *(36 - 46)* | |
| **Emissions gap for achieving 1.5°C** | | | 24 *(20 - 26)* | 32 *(20 - 37)* | Chapter 4 |
| **Energy sector** *(aggregated)* | **12.5** | **12.6** | **12.2** | **14.7** | |
| **Electricity production**[i] *(aggregated)* | **10.3** | **11** | **10.3** | **13** *(11.9 - 14.1)* | |
| Solar Energy[ii] | | | 4.2 | 7.9 *(7.0 – 9.6)* | (IEA 2023a; Det Norske Veritas [DNV] 2023; IRENA 2023; Nijsse *et al.* 2023; Bogdanov *et al.* 2019) |
| Wind Energy[ii] | | | 4.2 | 7.7 *(5.7 – 8.9)* | (IEA 2023a; DNV 2023; IRENA 2023; Teske ed. 2019) |
| Hydropower | | | 0.5 | 1.0 *(0.8 – 1.2)* | (IEA 2023a; DNV 2023; IRENA 2023) |
| Nuclear Energy | | | 0.4 | 0.8 *(0.6 – 1.0)* | (IEA 2023a; DNV 2023; IRENA 2023; Nuclear Energy Agency 2024) |
| Bioenergy excl. BECCS | | | 0.3 | 0.5 *(0.3 – 0.7)* | (IEA 2023a; IRENA 2023) |
| Bioelectricity with CCS (BECCS) | | | 0.1 | 0.5 *(0.4– 0.6)* | (IEA 2023a) |
| Carbon Capture and Storage (CCS) | | | 0.2 | 0.5 *(0.3 – 0.6)* | (IEA 2023a) |
| Geothermal | | | 0.5 | 0.6 *(0.2 – 1.0)* | (IEA 2023a; IRENA 2023; Teske ed. 2019) |
| **Methane from fossil fuels** *(aggregated)* | **2.2** | **1.6** | **1.9** | **1.7** *(1.3 - 2.1)* | |
| Reduce $CH_4$ emissions from coal mining | | | 0.5 | 0.4 *(0.3 – 0.5)* | (IEA 2024d) |
| Reduce $CH_4$ emissions from oil and gas | | | 1.4 | 1.2 *(0.9 – 1.6)* | (IEA 2024d) |
| **AFOLU** *(agriculture, forestry, demand-side aggregated)* | **12** | **13.6** | **8.0** *(4.1 – 16.7)* | **12.8** *(6.3 – 19.1)* | |
| **Agriculture** *(aggregated)* | **6.7** | **4.1** | **1.4** *(1.1 – 3.9)* | **2** *(1.3 - 2.1)* | |
| Improved rice production | | | 0.2 *(0.15 – 0.22)* | 0.2 *(0.15 – 0.22)* | Adapted from (Beach *et al.* 2015; United States of America, Environmental Protection Agency [EPA] 2019) |
| Nutrient management | | | 0.04 *(0.03 – 0.05)* | 0.04 *(0.03 – 0.05)* | Adapted from (Beach *et al.* 2015; EPA 2019) |
| Enteric fermentation | | | 0.17 *(0.13 – 0.18)* | 0.17 *(0.08 – 0.18)* | Adapted from (Beach *et al.* 2015; EPA 2019) |
| Manure management | | | 0.11 *(0.07 – 0.12)* | 0.1 *(0.07 – 0.12)* | Adapted from (Beach *et al.* 2015; EPA 2019) |

| | | | | | |
|---|---|---|---|---|---|
| Soil carbon mgmt (croplands & grasslands) | | | 0.9 *(0.4 – 1.6)* | 1.5 *(0.5 – 2.4)* | Adapted from (Nabuurs *et al.* 2022) |
| Agroforestry (croplands & grasslands) | | | 0.54 *(0.4 – 1.8)* | 0.54 *(0.3 – 1.8)* | (Naturebase 2024) |
| Biochar | | | 0.8 *(0.3 – 1.8)* | 1.1 *(0.3 – 1.8)* | Adapted from (Nabuurs *et al.* 2022) |
| **Forestry** *(aggregated)* | **5.3** | **7.3** | **5.9** *(2.7 – 8.9)* | **8.4** *(3.5 – 11.7)* | |
| Reduced deforestation | | | 1.8 *(1.6 – 4.0)* | 2.6 *(1.8 – 5.0)* | Adapted from (Austin *et al.* 2020) |
| Afforestation/ Reforestation | | | 2.6 *(0.5 – 3.0)* | 3.6 *(0.9 – 4.0)* | Adapted from (Austin *et al.* 2020) |
| Improved forest management | | | 1.5 *(0.6 – 1.9)* | 2.2 *(0.8 – 2.7)* | Adapted from (Austin *et al.* 2020) |
| **AFOLU demand-side** *(aggregated)* | *Included in agriculture* | **2.2** | **0.7** *(0.4 – 3.9)* | **2.4** *(1.1 – 3.7)* | |
| Reduced food waste | | | 0.2 *(0.1 – 0.9)* | 0.7 *(0.1 – 1.0)* | Adapted from (Nabuurs *et al.* 2022) |
| Shift to sustainable healthy diets | | | 0.5 *(0.3 – 3.0)* | 1.7 *(1.0 – 2.7)* | Adapted from (Nabuurs *et al.* 2022) |
| **Buildings** direct + indirect *(aggregated)* | **5.9** | **3.2** | **3.2** *(2.4 – 4.0)* | **4.2** *(2.3 - 5.2)* | |
| Avoid demand for energy services | | | 0.6 *(0.4 - 0.7)* | 0.8 *(0.6 – 1.0)* | (Cabeza *et al.* 2022) |
| New buildings - Better insulation | | | 0.6 *(0.5 – 0.8)* | 0.9 *(0.6 - 1.1)* | (Cabeza *et al.* 2022) |
| New buildings - Efficient heating & cooling | | | 0.6 *(0.5 – 0.8)* | 0.7 *(0.5 - 0.9)* | (Cabeza *et al.* 2022) |
| New buildings - Renewables | | | 0.4 *(0.3 - 0.5)* | 0.6 *(0.5 – 0.8)* | (Cabeza *et al.* 2022) |
| Retrofitting - Better insulation | | | 0.2 *(0.1 – 0.2)* | 0.2 *(0.1 – 0.2)* | (Cabeza *et al.* 2022) |
| Retrofitting - Efficient heating & cooling | | | 0.1 *(0.1 – 0.1)* | 0.1 *(0.1 – 0.1)* | (Cabeza *et al.* 2022) |
| Appliances[iii] | | | 0.7 *(0.5 – 0.9)* | 0.9 *(0.7 – 1.2)* | (Cabeza *et al.* 2022) |
| **Transport** *(aggregated)* | **4.7** | **3.8** | **3.2** *(1.6 – 4.8)* | **4.8** *(2.4 - 7.2)* | |
| **Road transport (aggregated)** | | | **2.5** *(1.2 – 3.7)* | **3.6** *(2.1 – 6.4)* | |
| Shifts to public transport | | | 0.8 *(0.4 – 1.2)* | 1.1 *(0.5 – 1.6)* | (Institute for Transportation & Development Policy [ITDP] and University of California [UC], Davis 2021; ITDP and UC Davis 2015) |
| Shifts to bikes and e-bikes | | | 0.3 *(0.1 – 0.4)* | 0.3 *(0.2 – 0.5)* | (ITDP and UC Davis 2021; ITDP and UC Davis 2015) |
| Shift to electric LDV[iv] | | | 0.3 *(0.2 – 0.5)* | 0.6 *(0.3 – 1.0)* | (IEA 2024b) |
| Shift to electric HDV[iv] | | | 0.1 *(0.0 – 0.1)* | 0.2 *(0.1 – 0.3)* | (IEA 2024b) |
| Fuel efficiency LDV | | | 0.5 *(0.3 – 0.8)* | 0.7 *(0.4 – 1.1)* | Based on (IEA 2023a) |
| Fuel efficiency HDV | | | 0.6 *(0.3 – 0.9)* | 1.1 *(0.5 – 1.6)* | Based on (IEA 2023a) |
| Biofuels | | | 0.2 *(0.1 – 0.3)* | 0.2 *(0.1 – 0.3)* | Based on (IEA 2023a) |
| **Shipping** *(aggregated)* | | | **0.2** *(0.1 – 0.3)* | **0.4** *(0.2 – 0.6)* | |
| Energy efficiency and optimisation, and a shift to low- and zero-emission fuels | | | 0.2 *(0.1 – 0.3)* | 0.4 *(0.2 – 0.6)* | Based on (IEA 2023a) |
| **Aviation** *(aggregated)* | | | **0.5** *(0.3 – 0.8)* | **0.8** *(0.4 – 1.2)* | |
| Reduced demand increase | | | 0.4 *(0.2 – 0.6)* | 0.5 *(0.3 – 0.8)* | (Bergero *et al.* 2023) |
| Energy efficiency and optimisation | | | 0.1 *(0.0 – 0.1)* | 0.1 *(0.1 – 0.2)* | Based on (Ziegler, Dupont and Han 2022) |

| | | | | | |
|---|---|---|---|---|---|
| Shift to low- and zero-emission fuels | | | 0.1 *(0.0 – 0.1)* | 0.2 *(0.1 – 0.3)* | Based on (Ziegler, Dupont and Han 2022) |
| Other | | | 0 *(0.0 – 0.0)* | 0.1 *(0.0 – 0.1)* | Based on (Ziegler, Dupont and Han 2022) |
| **Industry** *(aggregated)* | **5.4** | **5.4** | **4.4** *(4.2 – 4.8)* | **6.6** *(5.8 – 7.4)* | |
| Energy efficiency[v] | | | 1 *(1.0 - 1.1)* | 1.1 *(1.0 - 1.2)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022). |
| Material efficiency | | | 0.7 *(0.7 - 0.8)* | 1.2 *(1.1 - 1.4)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022). |
| Enhanced recycling | | | 0.6 *(0.5 - 0.6)* | 1 *(0.9 - 1.1)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022) |
| Fuel switching and electrification | | | 1.6 *(1.5 - 1.7)* | 2.1 *(1.8 - 2.3)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022) |
| Advanced feedstock decarbonization & process changes | | | 0.7 *(0.7 - 0.8)* | 1.2 *(1.1 - 1.3)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022) |
| CCU and CCS | | | 0.1 *(0.1 - 0.1)* | 0.5 *(0.4 - 0.6)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022) |
| Cementitious material substitution *(e.g., 1/3 ground limestone & 2/3 calcined clays, replacing <=50%* | | | 0.3 *(0.3 - 0.3)* | 0.4 *(0.4 - 0.5)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022) |
| Reduction of N2O emissions | | | 0.2 *(0.2 - 0.2)* | 0.3 *(0.3 - 0.3)* | Adapted from (Bashmakov *et al.* 2022; Babiker *et al.* 2022). |
| **Others** *(aggregated)* | | | **2.0** | **2.4** *(1.9 – 3.0)* | |
| **Fluorinated gases** | **-** | **1.2** | **1.2** | **1.4** *(1.0 - 1.8)* | (EPA 2019; Purohit and Höglund-Isaksson 2017) |
| **Waste and wastewater** | **0.4** | **0.7** | **0.8** | **1.0** *(0.9 - 1.2)* | |
| Reduced $CH_4$ emissions from solid waste | | | 0.6 | 0.8 *(0.65 - 0.84)* | (IPCC 2022; EPA 2019; Höglund-Isaksson *et al.* 2020) |
| Reduced CH4 emissions from wastewater | | | 0.2 | 0.3 *(0.28 - 0.31)* | (IPCC 2022; EPA 2019; Höglund-Isaksson *et al.* 2020) |
| **DACCS & enhanced weathering** | **1** | **-** | ***small*** | ***small*** | (Smith *et al.* eds. 2024; IPCC 2022; Young *et al.* 2023) |
| **Correction for overlap between sectors**[vi] | *Included in sector* | **-1.0** | **-2.3** | **-3.9** | |
| Electricity sector and Buildings | | -1.0 | -1.6 | -2.9 | |
| Electricity sector and Industry | | - | -0.7 | -1.0 | |

[i] For the aggregation of the total potential in the electricity sector, we use as a lower bound the trajectory set out in IEA NZE scenario (IEA 2023a) and as a higher bound a pathway towards zero emissions in 2040 (illustrated by National Renewable Energy Laboratory [2022]; Climate Action Tracker [2023]; Langer *et al.* [2024]).
[ii] 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 (Breyer *et al.* 2020; Bogdanov *et al.* 2021; Jacobson *et al.* 2019).These higher potentials were excluded in determining the mitigation potential.
[iii] Information from IEA (2024a) and UNEP (2023a) suggests mitigation potential for appliances could be double of what is reported here, but due to unclear baselines these estimates were excluded.
iv The emission reduction potential for EVs may be higher than reported in this table. The mitigation potential is based on IEA's recent Global EV Outlook (IEA 2024b), which uses lower baseline emissions compared to Chapter 4 of this report.
[v] Energy efficiency and some of the other options are partially market driven along with stock turnover, EE programs and regulation. Therefore, the aggregate was corrected for this autonomous implementation, assumed to be 15% of the total potential.
[vi] 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 Smit *et al.* (2024).

## References


Achakulwisut, P., Erickson, P., Guivarch, C., Schaeffer, R., Brutschin, E. and Pye, S. (2023). Global fossil fuel reduction pathways under different climate mitigation strategies and ambitions. *Nature Communications* 14(1), 5425. https://doi.org/10.1038/s41467-023-41105-z.

Austin, K.G., J.S. Baker, B L. Sohngen, C.M. Wade, A. Daigneault, S B. *et al.* (2020). The economic costs of planting, preserving, and managing the world's forests to mitigate climate change. *Nature Communications* 11(1), 5946. https://doi.org/10.1038/s41467-020-19578-z.

Babiker, M., Berndes, G., Blok, K., Cohen, B., Cowie, A., Geden, O. *et al.* (2022). Cross-sectoral perspectives. 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 12. 1245-1354. www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter12.pdf.

Bashmakov, I.A., Nilsson, L.J., Acquaye, A., Bataille, C., Cullen, J.M., de la Rue du Can, S. *et al.* (2022). Industry. 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 11. 1161-1244. www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter11.pdf.

Beach, R.H., Creason, J., Ohrel, S.B., Ragnauth, S., Ogle, S., Li, C. *et al.* (2015). Global mitigation potential and costs of reducing agricultural non-co2 greenhouse gas emissions through 2030. *Journal of Integrative Environmental Sciences* 12 (sup1), 87–105. https://doi.org/10.1080/1943815X.2015.1110183.

Bergero, C., Gosnell, G., Gielen, D., Kang, S., Bazilian, M. and Davis, S.J. (2023). Pathways to net-zero emissions from aviation. *Nature Sustainability* 6(4), 404–414. https://doi.org/10.1038/s41893-022-01046-9.

BloombergNEF (2024). *New Energy Outlook 2024*. London. https://about.bnef.com/new-energy-outlook.

Boehm, S., Jeffery, L., Hecke, J., Schumer, C., Jaeger, J., Fyson, C. *et al.* (2023). *State of Climate Action 2023*. Berlin and Cologne, San Francisco, CA and Washington, DC: Bezos Earth Fund, Climate Action Tracker, Climate Analytics, ClimateWorks Foundation, NewClimate Institute, the United Nations Climate Change High-Level Champions, and World Resources Institute. www.wri.org/research/state-climate-action-2023.

Bogdanov, D., Farfan, J., Sadovskaia, K., Aghahosseini, A., Child, M., Gulagi, A. (2019). Radical transformation pathway towards sustainable electricity via evolutionary steps. *Nature Communications* 10 (1), 1077. https://doi.org/10.1038/s41467-019-08855-1.

Bogdanov, D., Ram, M., Aghahosseini, A., Gulagi, A., Oyewo, A.S., Child, M. *et al.* (2021). Low-cost renewable electricity as the key driver of the global energy transition towards sustainability. *Energy* 227, 120467. https://doi.org/10.1016/j.energy.2021.120467.

Breyer, C., Bogdanov, D., Khalili, S. and Keiner, D. (2020). Solar photovoltaics in 100% renewable energy systems. In *Encyclopedia of Sustainability Science and Technology*. Meyers, R.A. (ed.). New York: Springer. 1–30. https://doi.org/10.1007/978-1-4939-2493-6_1071-1.

Badan Restorasi Gambut dan Mangrove Republik Indonesia (2023). *Sambut Awal Tahun, BRGM Gelar Rakor Dan Serahkan DIPA Ke 7 Provinsi Restorasi Gambut*. Bali. https://ppid.brgm.go.id/sambut-awal-tahun-brgm-gelar-rakor-dan-serahkan-dipa-ke-7-provinsi-restorasi-gambut/.

Cabeza, L.F., Bai, Q., Bertoldi, P., Kihila, J.M., Lucena, A.F.P., Mata, É. *et al.* (2022). Buildings. 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 9. 1245-1354. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter09.pdf.

Climate Action Tracker (2023). *Pulling the Plug on Fossils in Power*. Berlin and Cologne, Germany. https://climateactiontracker.org/publications/pulling-the-plug-on-fossils-in-power.

Det Norske Veritas (2023). *Pathway to Net-zero Emissions: Energy Transitions Outlook 2023*. https://www.dnv.com/ publications/pathway-to-net-zero-emissions-report-2023-249543/.

Falk, J., Gaffney, O., Bhowmik, A.K., Bergmark, P., Galaz, V., Gaskell, N. *et al.* (2020). *Exponential Roadmap: Scaling 36 Solutions to Halve Emissions by 2030*. Sweden: Future Earth. https://exponentialroadmap.org/wp-content/uploads/2020/03/ExponentialRoadmap_1.5.1_216x279_08_AW_Download_Singles_Small.pdf.

Food and Agriculture Organization of the United Nations (2023). *Achieving SDG2 without Breaching the 1.5C Threshold: A Global Roadmap*. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/interactive/sdg2-roadmap/assets/3d-models/inbrief-roadmap.pdf.

Grant, N., Aboumahboub, T., Welder, L. and Fyson, C. (2024). *Tripling Renewables by 2030: Interpreting the Global Goal at the Regional Level*. Berlin: Climate Analytics. https://climateanalytics.org/publications/tripling-renewables-by-2030-interpreting-the-global-goal-at-the-regional-level.

Höglund-Isaksson, L., Gómez-Sanabria, A., Klimont, Z., Rafaj, P. and Schöpp, W. (2020). Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS Model. *Environmental Research Communications* 2(2), 025004. https://doi.org/10.1088/2515-7620/ab7457.

Humpenöder, F., Karstens, K., Lotze-Campen, H., Leifeld, J., Menichetti, L., Barthelmes, A. and Popp, A. (2020). Peatland protection and restoration are key for climate change mitigation. *Environmental Research Letters* 15(10), 104093. https://doi.org/10.1088/1748-9326/abae2a.

International Energy Agency (2023a). *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach: 2023 Update*. Paris. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.

_________ (2023b). *Tracking Clean Energy Progress 2023*. Paris. https://www.iea.org/reports/tracking-clean-energy-progress-2023.

_________ (2023c). *World Energy Outlook 2023*. Paris. https://www.iea.org/reports/world-energy-outlook-2023.

_________ (2024a). Buildings, undated. Paris. https://www.iea.org/energy-system/buildings.

_________ (2024b). *Global EV Outlook 2024*. Paris. https://www.iea.org/reports/global-ev-outlook-2024.

_________ (2024d). *Global Methane Tracker 2024*. Paris. https://www.iea.org/reports/global-methane-tracker-2024.

Intergovernmental Panel on Climate Change (2022). *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. https://www.ipcc.ch/report/ar6/wg3.

International Renewable Energy Agency (2023). *World Energy Transitions Outlook 2023: 1.5°C Pathway*. Abu Dhabi. https://www.irena.org/Publications/2023/Jun/World-Energy-Transitions-Outlook-2023.

_________ (2024). *Renewable Energy Highlights*. Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/Renewable_energy_highlights_FINAL_July_2024.pdf.

Institute for Transportation & Development Policy and University of California, Davis (2015). *A Global High Shift Cycling Scenario: The Potential for Dramatically Increasing Bicycle and E-bike Use in Cities Around the World, with Estimated Energy, CO2, and Cost Impacts*. www.bisikletizm.com/wp-content/uploads/2016/03/A-Global-High-Shift-Cycling-Scenario_Bisikletli-Ulasim-Senaryosu.pdf.

_________ (2021). *The Compact City Scenario - Electrified. The Only Way to 1.5 °C*. New York and Davis. https://itdp.org/wp-content/uploads/2021/12/EN_Compact-Cities-REPORT_SINGLEPAGE-1.pdf.

Jacobson, M.Z., Delucchi, M.A., Cameron, M.A., Coughlin, S.J., Hay, C.A., Manogaran, I.P. *et al.* (2019). Impacts of green new deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries. *One Earth* 1(4), 449-463. https://doi.org/10.1016/j.oneear.2019.12.003.

Langer, Jannis, Francesco Lombardi, Stefan Pfenninger, Harkunti P. Rahayu, Muhammad Indra Al Irsyad, and Kornelis Blok. 2024. “The Role of Inter-Island Transmission in Full Decarbonisation Scenarios for Indonesia’s Power Sector.” *Environmental Research: Energy* 1 (2): 025006. https://doi.org/10.1088/2753-3751/ad53cb.

LC3 (2024). *Limestone Calcined Clay Cement*. Lausanne, Switzerland. https://lc3.ch/.

Mission Possible Partnership (2022a). *Making Net-Zero Steel Possible*. Geneva, Switzerland. https://missionpossiblepartnership.org/wp-content/uploads/2022/09/Making-Net-Zero-Steel-possible.pdf.

_________ (2022b). Mission Possible Partnership - 2030 Milestones, undated. Geneva, Switzerland. https://www.missionpossiblepartnership.org/news/2022/11/14/2030-milestones/.

_________ (2023). *Making Net-Zero Concrete and Cement Possible*. Geneva, Switzerland. https://www.missionpossiblepartnership.org/making-net-zero-concrete-and-cement-possible-report/.

Murray, N.J., Worthington, T.A., Bunting, P., Duce, S., Hagger, V., Lovelock, C.E. *et al.* (2022). High-resolution mapping of losses and gains of earth's tidal wetlands. *Science* 376(6594), 744–749. https://doi.org/10.1126/science.abm9583.

Nabuurs, G.-J., Mrabet, R., Abu Hatab, A., Bustamante, M., Clark, H., Havlik, P. *et al.* (2022). Agriculture, forestry and other land uses (AFOLU). 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., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (eds.). Cambridge and New York: Cambridge University Press. Chapter 7. 747-860. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter07.pdf.

Naturebase (2024). Cropland Based Agroforestry V2. https://naturebase.org.

Nijsse, F.J., Mercure, J.F., Ameli, N., Larosa, F., Kothari, S., Rickman, J. (2023). The momentum of the solar energy transition. *Nature Communications* 14(1), 6542. https://doi.org/10.1038/s41467-023-41971-7.

National Renewable Energy Laboratory (2022). *Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035.* Golden, Colorado. https://www.nrel.gov/docs/fy22osti/81644.pdf.

Nuclear Energy Agency (2024). *Meeting Climate Change Targets: The Role of Nuclear Energy*. Paris. https://www.oecd-nea.org/jcms/pl_69396/meeting-climate-change-targets-the-role-of-nuclear-energy.

Purohit, P. and Höglund-Isaksson, L. (2017). Global emissions of fluorinated greenhouse gases 2005–2050 with abatement potentials and costs. *Atmospheric Chemistry and Physics* 17(4), 2795–2816. https://doi.org/10.5194/acp-17-2795-2017.

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A., *et al.* (2021). Land-based measures to mitigate climate change: potential and feasibility by country. *Global Change Biology* 27(23), 6025–6058. https://doi.org/10.1111/gcb.15873.

Schumer, C., Boehm, S., Jaeger, J. Fyson, C. Hecke, J., Jeffery, L. *et al.* (2024). *Methodology Underpinning the State of Climate Action Series: 2024 Update*. Washington, DC: World Resources Institute. https://doi.org/10.46830/writn.23.00043.v2.

Sirin, A. A. (2022). Mires and peatlands: carbon, greenhouse gases, and climate change. *Biology Bulletin Reviews* 12(S2): S123–S139. https://doi.org/10.1134/S2079086422080096.

Smith, S.M., Geden, O., Gidden, M.J., Lamb, W.F., Nemet, G.F., Minx, J.C. *et al.* (eds.). (2024). *The State of Carbon Dioxide Removal - 2nd Edition*. https://osf.io/f85qj/.

Teske, S. (ed.). (2019). *Achieving the Paris Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5℃ and +2℃*. Sydney: Springer Open. https://library.oapen.org/handle/20.500.12657/22899.

United Nations Environment Programme (2021). *Food Waste Index Report 2021*. Nairobi. https://www.unep.org/resources/report/unep-food-waste-index-report-2021.

__________ (2022). *Global Peatlands Assessment – The State of the World's Peatlands: Evidence for Action toward the Conservation, Restoration, and Sustainable Management of Peatlands. Main Report*. Nairobi. https://www.unep.org/resources/global-peatlands-assessment-2022.

__________ (2023). *Global Cooling Watch 2023: Keeping it Chill: How to meet cooling demands while cutting emissions*. Nairobi. https://www.unep.org/resources/global-cooling-watch-2023.

United Nations Environment Programme Copenhagen Climate Centre and Common Futures (2024). *Sectoral Greenhouse Gas Emissions Mitigation Potentials in 2035*. Copenhagen. https://unepccc.org/publications/bridging-the-gap-sectoral-greenhouse-gas-mitigation-potentials-in-2035/.

United States of America, Environmental Protection Agency (2019). *Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation: 2015–2050*. Washington, DC. https://www.epa.gov/sites/default/files/2019-09/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf.

Wolosin, M., Hole, D., Griscom, B., Rockström, J., Barrera, L., Beringer, T. *et al.* (2022). *Exponential Roadmap for Natural Climate Solutions*. Washington, D.C.: Conservation International. https://www.conservation.org/priorities/exponential-roadmap-natural-climate-solutions.

Young, J., McQueen, N., Charalambous, C., Foteinis, S., Hawrot, O. *et al.* (2023). The cost of direct air capture and storage can be reduced via strategic deployment but is unlikely to fall below stated cost targets. *One Earth* 6(7), 899–917. https://doi.org/10.1016/j.oneear.2023.06.004.

Ziegler, U., Dupont, R.A.B. and Han, T.K. (2022). ICAO Committee on Aviation Environmental Protection. In *Innovation for a Green Transition: ICAO Environmental Report 2022.* Montreal, Canada: International Civil Aviation Organization. Chapter 1. 20–23. www.icao.int/environmental-protection/Documents/EnvironmentalReports/2022/ENVReport2022_Art6.pdf.

**Special thanks to UNEP's funding partners.** For more than 50 years, UNEP has served as the leading global authority on the environment, mobilizing action through scientific evidence, raising awareness, building capacity and convening stakeholders. UNEP's core programme of work is made possible by flexible contributions from Member States and other partners to the Environment Fund and UNEP Planetary Funds. These funds enable agile, innovative solutions for climate change, nature and biodiversity loss, and pollution and waste.

**Support UNEP. Invest in people and planet.**
www.unep.org/funding

UN environment programme

www.unep.org
unep-communication-director@un.org