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Mitigation of Climate Change

Summary for Policymakers



WGIII

Working Group III contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change



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**WORKING GROUP III CONTRIBUTION
TO THE IPCC SIXTH ASSESSMENT REPORT (AR6)**

Summary for Policymakers

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A. Introduction and framing

The Working Group III (WG III) contribution to the IPCC's Sixth Assessment Report (AR6) assesses literature on the scientific, technological, environmental, economic and social aspects of mitigation of climate change. [FOOTNOTE 1] Levels of confidence [FOOTNOTE 2] are given in () brackets. Numerical ranges are presented in square [] brackets. References to Chapters, Sections, Figures and Boxes in the underlying report and Technical Summary (TS) are given in {} brackets.

FOOTNOTE 1: The Report covers literature accepted for publication by 11 October 2021.

FOOTNOTE 2: Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers, typeset in italics: *very low*, *low*, *medium*, *high* and *very high*. The assessed likelihood of an outcome or a result is described as: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, more likely than not 50–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms may also be used when appropriate, consistent with the IPCC uncertainty guidance: <https://www.ipcc.ch/site/assets/uploads/2018/05/uncertainty-guidance-note.pdf>.

The report reflects new findings in the relevant literature and builds on previous IPCC reports, including the WG III contribution to the IPCC's Fifth Assessment Report (AR5), the WG I and WG II contributions to AR6 and the three Special Reports in the Sixth Assessment cycle, [FOOTNOTE 3] as well as other UN assessments. Some of the main developments relevant for this report include {TS.1, TS.2}:

FOOTNOTE 3: The three Special Reports are: Global Warming of 1.5°C: an IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018); Climate Change and Land: an IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (2019); IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019).

- **An evolving international landscape.** The literature reflects, among other factors: developments in the UN Framework Convention on Climate Change (UNFCCC) process, including the outcomes of the Kyoto Protocol and the adoption of the Paris Agreement {13, 14, 15, 16}; the UN 2030 Agenda for Sustainable Development including the Sustainable Development Goals (SDGs) {1, 3, 4, 17}; and the evolving roles of international cooperation {14}, finance {15} and innovation {16}.
- **Increasing diversity of actors and approaches to mitigation.** Recent literature highlights the growing role of non-state and sub-national actors including cities, businesses, Indigenous Peoples, citizens including local communities and youth, transnational initiatives, and public-private entities in the global effort to address climate change {5, 13, 14, 15, 16, 17}. Literature documents the global spread of climate policies and cost declines of existing and emerging low emission technologies, along with varied types and levels of mitigation efforts, and sustained reductions in greenhouse gas (GHG) emissions in some countries {2, 5, 6, 8, 12, 13, 16}, and the impacts of, and some lessons from, the COVID-19 pandemic. {1, 2, 3, 5, 13, 15, Box TS.1, Cross-Chapter Box 1 in Chapter 1}

- **Close linkages between climate change mitigation, adaptation and development pathways.** The development pathways taken by countries at all stages of economic development impact GHG emissions and hence shape mitigation challenges and opportunities, which vary across countries and regions. Literature explores how development choices and the establishment of enabling conditions for action and support influence the feasibility and the cost of limiting emissions {1, 3, 4, 5, 13, 15, 16}. Literature highlights that climate change mitigation action designed and conducted in the context of sustainable development, equity, and poverty eradication, and rooted in the development aspirations of the societies within which they take place, will be more acceptable, durable and effective {1, 3, 4, 5}. This report covers mitigation from both targeted measures, and from policies and governance with other primary objectives.
- **New approaches in the assessment.** In addition to the sectoral and systems chapters {3, 6, 7, 8, 9, 10, 11, 12}, the report includes, for the first time in a WG III report, chapters dedicated to demand for services, and social aspects of mitigation {5, Box TS.11}, and to innovation, technology development and transfer {16}. The assessment of future pathways in this report covers near term (to 2030), medium term (up to 2050), and long term (to 2100) timescales, combining assessment of existing pledges and actions {4, 5}, with an assessment of emissions reductions, and their implications, associated with long-term temperature outcomes up to the year 2100 {3}. [FOOTNOTE 4] The assessment of modelled global pathways addresses ways of shifting development pathways towards sustainability. Strengthened collaboration between IPCC Working Groups is reflected in Cross-Working Group boxes that integrate physical science, climate risks and adaptation, and the mitigation of climate change. [FOOTNOTE 5]

FOOTNOTE 4: The term ‘temperature’ is used in reference to “global surface temperatures” throughout this SPM as defined in footnote 8 of WG I SPM. See FOOTNOTE 14 of Table SPM.1. Emission pathways and associated temperature changes are calculated using various forms of models, as summarised in Box SPM.1 and Chapter 3 and discussed in Annex III.

FOOTNOTE 5: Namely: Economic Benefits from Avoided Climate Impacts along Long-Term Mitigation Pathways {Cross-Working Group Box 1 in Chapter 3}; Urban: Cities and Climate Change {Cross-Working Group Box 2 in Chapter 8}; and Mitigation and Adaptation via the Bioeconomy {Cross-Working Group Box 3 in Chapter 12}.

- **Increasing diversity of analytic frameworks from multiple disciplines including social sciences.** This report identifies multiple analytic frameworks to assess the drivers of, barriers to and options for, mitigation action. These include: economic efficiency including the benefits of avoided impacts; ethics and equity; interlinked technological and social transition processes; and socio-political frameworks, including institutions and governance {1, 3, 13, Cross-Chapter Box 12 in Chapter 16}. These help to identify risks and opportunities for action including co-benefits and just and equitable transitions at local, national and global scales. {1, 3, 4, 5, 13, 14, 16, 17}

Section B of this Summary for Policymakers (SPM) assesses *Recent developments and current trends*, including data uncertainties and gaps. Section C, *System transformations to limit global warming*, identifies emission pathways and alternative mitigation portfolios consistent with limiting global warming to different levels, and assesses specific mitigation options at the sectoral and system level. Section D addresses *Linkages between mitigation, adaptation, and sustainable development*. Section E, *Strengthening the response*, assesses knowledge of how enabling conditions of institutional design, policy, finance, innovation and governance arrangements can contribute to climate change mitigation in the context of sustainable development.

B. Recent developments and current trends

B.1 Total net anthropogenic GHG emissions [FOOTNOTE 6] have continued to rise during the period 2010–2019, as have cumulative net CO₂ emissions since 1850. Average annual GHG emissions during 2010–2019 were higher than in any previous decade, but the rate of growth between 2010 and 2019 was lower than that between 2000 and 2009. (*high confidence*) (Figure SPM.1) {Figure 2.2, Figure 2.5, Table 2.1, 2.2, Figure TS.2}

FOOTNOTE 6: Net GHG emissions in this report refer to releases of greenhouse gases from anthropogenic sources minus removals by anthropogenic sinks, for those species of gases that are reported under the common reporting format of the United Nations Framework Convention on Climate Change (UNFCCC): CO₂ from fossil fuel combustion and industrial processes (CO₂-FFI); net CO₂ emissions from land use, land use change and forestry (CO₂-LULUCF); methane (CH₄); nitrous oxide (N₂O); and fluorinated gases (F-gases) comprising hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) as well as nitrogen trifluoride (NF₃). Different datasets for GHG emissions exist, with varying time horizons and coverage of sectors and gases, including some that go back to 1850. In this report, GHG emissions are assessed from 1990, and CO₂ sometimes also from 1850. Reasons for this include data availability and robustness, scope of the assessed literature, and the differing warming impacts of non-CO₂ gases over time.

B.1.1 Global net anthropogenic GHG emissions were 59±6.6 GtCO₂-eq [FOOTNOTE 7, 8] in 2019, about 12% (6.5 GtCO₂-eq) higher than in 2010 and 54% (21 GtCO₂-eq) higher than in 1990. The annual average during the decade 2010–2019 was 56±6.0 GtCO₂-eq, 9.1 GtCO₂-eq yr⁻¹ higher than in 2000–2009. This is the highest increase in average decadal emissions on record. The average annual rate of growth slowed from 2.1% yr⁻¹ between 2000 and 2009 to 1.3% yr⁻¹ between 2010 and 2019. (*high confidence*) (Figure SPM.1) {Figure 2.2, Figure 2.5, Table 2.1, 2.2, Figure TS.2}

FOOTNOTE 7: GHG emission metrics are used to express emissions of different greenhouse gases in a common unit. Aggregated GHG emissions in this report are stated in CO₂-equivalent (CO₂-eq) using the Global Warming Potential with a time horizon of 100 years (GWP100) with values based on the contribution of Working Group I to the AR6. The choice of metric depends on the purpose of the analysis and all GHG emission metrics have limitations and uncertainties, given that they simplify the complexity of the physical climate system and its response to past and future GHG emissions. {Chapter 2 SM 2.3, Cross-Chapter Box 2 in Chapter 2, Box TS.2, WG I Chapter 7 Supplementary Material}

FOOTNOTE 8: In this SPM, uncertainty in historic GHG emissions is reported using 90 % uncertainty intervals unless stated otherwise. GHG emission levels are rounded to two significant digits; as a consequence, small differences in sums due to rounding may occur.

B.1.2 Growth in anthropogenic emissions has persisted across all major groups of GHGs since 1990, albeit at different rates. By 2019, the largest growth in absolute emissions occurred in CO₂ from fossil fuels and industry followed by CH₄, whereas the highest relative growth occurred in fluorinated gases, starting from low levels in 1990 (*high confidence*). Net anthropogenic CO₂ emissions from land use, land-use change and forestry (CO₂-LULUCF) are subject to large uncertainties and high annual variability, with *low confidence* even in the direction of the long-term trend [FOOTNOTE 9]. (Figure SPM.1) {Figure 2.2, Figure 2.5, 2.2, Figure TS.2}

FOOTNOTE 9: Global databases make different choices about which emissions and removals occurring on land are considered anthropogenic. Currently, net CO₂ fluxes from land reported by global book-keeping models used here are estimated to be about ~5.5 GtCO₂ yr⁻¹ higher than the aggregate

global net emissions based on national GHG inventories. This difference, which has been considered in the literature, mainly reflects differences in how anthropogenic forest sinks and areas of managed land are defined. Other reasons for this difference, which are more difficult to quantify, can arise from the limited representation of land management in global models and varying levels of accuracy and completeness of estimated LULUCF fluxes in national GHG inventories. Neither method is inherently preferable. Even when the same methodological approach is applied, the large uncertainty of CO₂-LULUCF emissions can lead to substantial revisions to estimated emissions. {Cross-Chapter Box 3 in Chapter 3, 7.2, SRCCL SPM A.3.3}

B.1.3 Historical cumulative net CO₂ emissions from 1850 to 2019 were 2400±240 GtCO₂ (*high confidence*). Of these, more than half (58%) occurred between 1850 and 1989 [1400±195 GtCO₂], and about 42% between 1990 and 2019 [1000±90 GtCO₂]. About 17% of historical cumulative net CO₂ emissions since 1850 occurred between 2010 and 2019 [410±30 GtCO₂]. [FOOTNOTE 10] By comparison, the current central estimate of the remaining carbon budget from 2020 onwards for limiting warming to 1.5°C with a probability of 50% has been assessed as 500 Gt CO₂, and as 1150 Gt CO₂ for a probability of 67% for limiting warming to 2°C. Remaining carbon budgets depend on the amount of non-CO₂ mitigation (±220 Gt CO₂) and are further subject to geophysical uncertainties. Based on central estimates only, cumulative net CO₂ emissions between 2010-2019 compare to about four fifths of the size of the remaining carbon budget from 2020 onwards for a 50% probability of limiting global warming to 1.5°C, and about one third of the remaining carbon budget for a 67% probability to limit global warming to 2°C. Even when taking uncertainties into account, historical emissions between 1850 and 2019 constitute a large share of total carbon budgets for these global warming levels [FOOTNOTE 11, 12]. Based on central estimates only, historical cumulative net CO₂ emissions between 1850-2019 amount to about four fifths [FOOTNOTE 12] of the total carbon budget for a 50% probability of limiting global warming to 1.5°C (central estimate about 2900 GtCO₂), and to about two thirds [FOOTNOTE 12] of the total carbon budget for a 67% probability to limit global warming to 2°C (central estimate about 3550 GtCO₂). {Figure 2.7, 2.2, Figure TS.3, WG I Table SPM.2}

FOOTNOTE 10: For consistency with WGI, historical cumulative CO₂ emissions from 1850-2019 are reported using 68% confidence intervals.

FOOTNOTE 11: The carbon budget is the maximum amount of cumulative net global anthropogenic CO₂ emissions that would result in limiting global warming to a given level with a given likelihood, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date. The total carbon budgets reported here are the sum of historical emissions from 1850 to 2019 and the remaining carbon budgets from 2020 onwards, which extend until global net zero CO₂ emissions are reached. {Annex I: Glossary; WG I SPM}

FOOTNOTE 12: Uncertainties for total carbon budgets have not been assessed and could affect the specific calculated fractions.

B.1.4 Emissions of CO₂-FFI dropped temporarily in the first half of 2020 due to responses to the COVID-19 pandemic (*high confidence*), but rebounded by the end of the year (*medium confidence*). The annual average CO₂-FFI emissions reduction in 2020 relative to 2019 was about 5.8% [5.1-6.3%], or 2.2 [1.9-2.4] GtCO₂ (*high confidence*). The full GHG emissions impact of the COVID-19 pandemic could not be assessed due to a lack of data regarding non-CO₂ GHG emissions in 2020. {Cross-Chapter Box 1 in Chapter 1, Figure 2.6, 2.2, Box TS.1, Box TS.1 Figure 1}

Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.

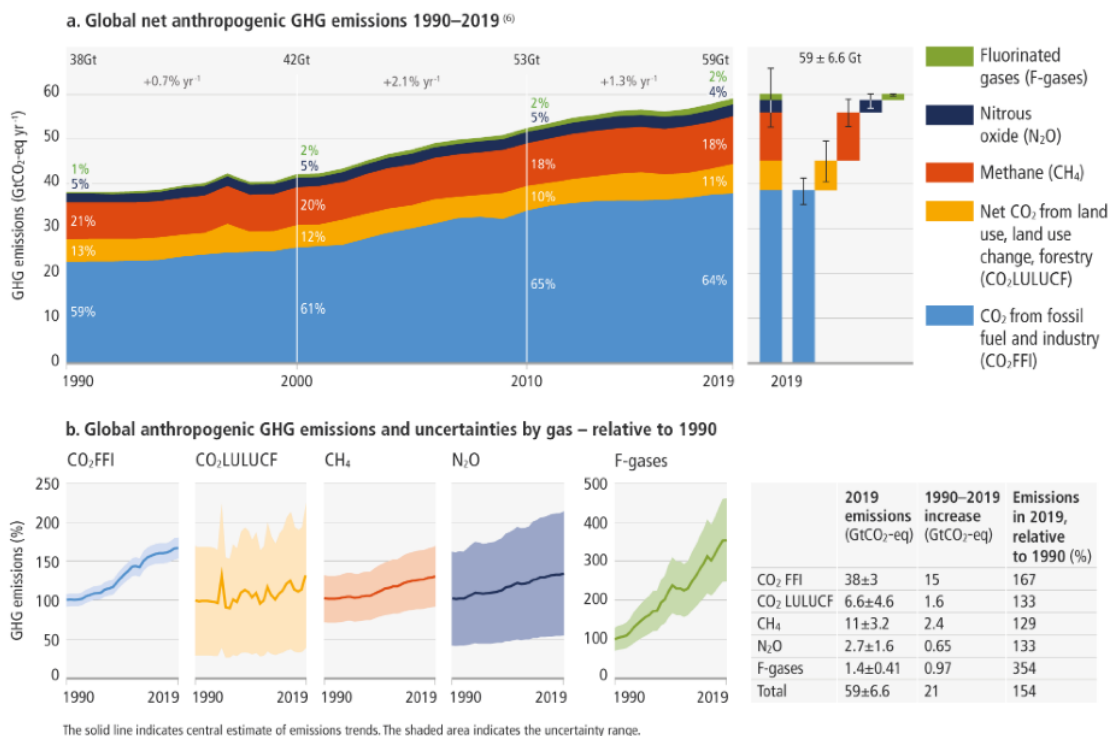


Figure SPM.1: Global net anthropogenic GHG emissions (GtCO₂-eq yr⁻¹) 1990–2019

Global net anthropogenic GHG emissions include CO₂ from fossil fuel combustion and industrial processes (CO₂-FFI); net CO₂ from land use, land use change and forestry (CO₂-LULUCF) [FOOTNOTE 9]; methane (CH₄); nitrous oxide (N₂O); fluorinated gases (HFCs; PFCs, SF₆, NF₃). [FOOTNOTE 6]

Panel a shows aggregate annual global net anthropogenic GHG emissions by groups of gases from 1990 to 2019 reported in GtCO₂-eq converted based on global warming potentials with a 100-year time horizon (GWP100-AR6) from the IPCC Sixth Assessment Report Working Group I (Chapter 7). The fraction of global emissions for each gas is shown 1990, 2000, 2010, 2019; as well as the aggregate average annual growth rate between these decades. At the right side of Panel a, GHG emissions in 2019 are broken down into individual components with the associated uncertainties [90% confidence interval] indicated by the error bars: CO₂ FFI ±8%, CO₂-LULUCF ±70%, CH₄ ±30%, N₂O ±60%, F-gases ±30%, GHG ±11%. Uncertainties in GHG emissions are assessed in the Supplementary Material to Chapter 2. The single year peak of emissions in 1997 was due to higher CO₂-LULUCF emissions from a forest and peat fire event in South East Asia.

Panel b shows global anthropogenic CO₂-FFI, net CO₂-LULUCF, CH₄, N₂O and fluorinated gas emissions individually for the period 1990–2019, normalised relative to 100 in 1990. Note the different scale for the included fluorinated gas emissions compared to other gases, highlighting its rapid growth from a low base. Shaded areas indicate the uncertainty range. Uncertainty ranges as shown here are specific for individual groups of greenhouse gases and cannot be compared. The table shows the central estimate for: absolute emissions in 2019, the absolute change in emissions between 1990 and 2019, and emissions in 2019 expressed as a percentage of 1990 emissions. {2.2, Figure 2.5, Figure TS.2, Chapter 2 SM}

FOOTNOTE 9: Global databases make different choices about which emissions and removals occurring on land are considered anthropogenic. Currently, net CO₂ fluxes from land reported by global book-keeping models used here are estimated to be about ~5.5 GtCO₂ yr⁻¹ higher than the aggregate global net emissions based on national GHG inventories. This difference, which has been considered in the literature, mainly reflects differences in how anthropogenic forest sinks and areas of managed land are defined. Other reasons for this difference, which are more difficult to quantify, can arise from the limited representation of land management in global models and varying levels of accuracy and completeness of estimated LULUCF fluxes in national GHG inventories. Neither method is inherently preferable. Even when the same methodological approach is applied, the large uncertainty of CO₂-LULUCF emissions can lead to substantial revisions to estimated emissions. {Cross-Chapter Box 3 in Chapter 3, 7.2, SRCCCL SPM A.3.3}

FOOTNOTE 6: Net GHG emissions in this report refer to releases of greenhouse gases from anthropogenic sources minus removals by anthropogenic sinks, for those species of gases that are reported under the common reporting format of the United Nations Framework Convention on Climate Change (UNFCCC): CO₂ from fossil fuel combustion and industrial processes (CO₂-FFI); net CO₂ emissions from land use, land use change and forestry (CO₂-LULUCF); methane (CH₄); nitrous oxide (N₂O); and fluorinated gases (F-gases) comprising hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) as well as nitrogen trifluoride (NF₃). Different datasets for GHG emissions exist, with varying time horizons and coverage of sectors and gases, including some that go back to 1850. In this report, GHG emissions are assessed from 1990, and CO₂ sometimes also from 1850. Reasons for this include data availability and robustness, scope of the assessed literature, and the differing warming impacts of non-CO₂ gases over time.

B.2 Net anthropogenic GHG emissions have increased since 2010 across all major sectors globally. An increasing share of emissions can be attributed to urban areas. Emissions reductions in CO₂ from fossil fuels and industrial processes, due to improvements in energy intensity of GDP and carbon intensity of energy, have been less than emissions increases from rising global activity levels in industry, energy supply, transport, agriculture and buildings. (*high confidence*) {2.2, 2.4, 6.3, 7.2, 8.3, 9.3, 10.1, 11.2}

B.2.1 In 2019, approximately 34% [20 GtCO₂-eq] of total net anthropogenic GHG emissions came from the energy supply sector, 24% [14 GtCO₂-eq] from industry, 22% [13 GtCO₂-eq] from agriculture, forestry and other land use (AFOLU), 15% [8.7 GtCO₂-eq] from transport and 6% [3.3 GtCO₂-eq] from buildings.¹³ If emissions from electricity and heat production are attributed to the sectors that use the final energy, 90% of these indirect emissions are allocated to the industry and buildings sectors, increasing their relative GHG emissions shares from 24% to 34%, and from 6% to 16%, respectively. After reallocating emissions from electricity and heat production, the energy supply sector accounts for 12% of global net anthropogenic GHG emissions. (*high confidence*) {Figure 2.12, 2.2, 6.3, 7.2, 9.3, 10.1, 11.2, Figure TS.6}

FOOTNOTE 13: Sector definitions can be found in Annex II 9.1.

B.2.2 Average annual GHG emissions growth between 2010 and 2019 slowed compared to the previous decade in energy supply [from 2.3% to 1.0%] and industry [from 3.4% to 1.4%], but remained roughly constant at about 2% per year in the transport sector (*high confidence*). Emissions growth in AFOLU, comprising emissions from agriculture (mainly CH₄ and N₂O) and forestry and other land use (mainly CO₂) is more uncertain than in other sectors due to the high share and uncertainty of CO₂-LULUCF emissions (*medium confidence*). About half of total net AFOLU emissions are from CO₂-LULUCF, predominantly from deforestation. [FOOTNOTE 14] (*medium confidence*). {Figure 2.13, 2.2, 6.3, 7.2, Figure 7.3, 9.3, 10.1, 11.2, TS.3}

FOOTNOTE 14: Land overall constituted a net sink of $-6.6 (\pm 4.6)$ GtCO₂ yr⁻¹ for the period 2010-2019, comprising a gross sink of $-12.5 (\pm 3.2)$ GtCO₂ yr⁻¹ resulting from responses of all land to both anthropogenic environmental change and natural climate variability, and net anthropogenic CO₂-LULUCF emissions $+5.9 (\pm 4.1)$ GtCO₂ yr⁻¹ based on book-keeping models. {2.2, 7.2, Table 7.1}

B.2.3 The global share of emissions that can be attributed to urban areas is increasing. In 2015, urban emissions were estimated to be 25 GtCO₂-eq (about 62% of the global share) and in 2020, 29 GtCO₂-eq (67-72% of the global share).¹⁵ The drivers of urban GHG emission are complex and include population size, income, state of urbanisation and urban form. (*high confidence*) {8.1, 8.3}

FOOTNOTE 15: This estimate is based on consumption-based accounting, including both direct emissions from within urban areas, and indirect emissions from outside urban areas related to the production of electricity, goods and services consumed in cities. These estimates include all CO₂ and CH₄ emission categories except for aviation and marine bunker fuels, land-use change, forestry and agriculture. {8.1, Annex I: Glossary}

B.2.4 Global energy intensity (total primary energy per unit GDP) decreased by 2% yr⁻¹ between 2010 and 2019. Carbon intensity (CO₂ from fossil fuel combustion and industrial processes (CO₂ FFI) per unit primary energy) decreased by 0.3% yr⁻¹, with large regional variations, over the same period mainly due to fuel switching from coal to gas, reduced expansion of coal capacity, and increased use of renewables. This reversed the trend observed for 2000–2009. For comparison, the carbon intensity of primary energy is projected to decrease globally by about 3.5% yr⁻¹ between 2020 and 2050 in modelled scenarios that limit warming to 2°C (>67%), and by about 7.7% yr⁻¹ globally in scenarios that limit warming to 1.5°C (>50%) with no or limited overshoot.¹⁶ (*high confidence*) {Figure 2.16, 2.2, 2.4, Table 3.4, 3.4, 6.3}

FOOTNOTE 16: See Box SPM.1 for the categorisation of modelled long-term emission scenarios based on projected temperature outcomes and associated probabilities adopted in this report.

B.3 Regional contributions [FOOTNOTE 17] to global GHG emissions continue to differ widely. Variations in regional, and national per capita emissions partly reflect different development stages, but they also vary widely at similar income levels. The 10% of households with the highest per capita emissions contribute a disproportionately large share of global household GHG emissions. At least 18 countries have sustained GHG emission reductions for longer than 10 years. (*high confidence*) (Figure SPM.2) {Figure 1.1, Figure 2.9, Figure 2.10, Figure 2.25, 2.2, 2.3, 2.4, 2.5, 2.6, Figure TS.4, Figure TS.5}

FOOTNOTE 17: See Working Group III Annex II, Part 1 for regional groupings adopted in this report.

B.3.1 GHG emissions trends over 1990-2019 vary widely across regions and over time, and across different stages of development as shown in Figure SPM.2. Average global per capita net anthropogenic GHG emissions increased from 7.7 to 7.8 tCO₂-eq, ranging from 2.6 tCO₂-eq to 19 tCO₂-eq across regions. Least Developed Countries (LDCs) and Small Island Developing States (SIDS) have much lower per capita emissions (1.7 tCO₂-eq, 4.6 tCO₂-eq, respectively) than the global average (6.9 tCO₂-eq), excluding CO₂-LULUCF [FOOTNOTE 18]. (*high confidence*) (Figure SPM.2) {Figure 1.2, Figure 2.9, Figure 2.10, 2.2, Figure TS.4}

FOOTNOTE 18: In 2019, LDCs are estimated to have emitted 3.3% of global GHG emissions, and SIDS are estimated to have emitted 0.60% of global GHG emissions, excluding CO₂-LULUCF. These

country groupings cut across geographic regions and are not depicted separately in Fig SPM2. {Figure 2.10}

B.3.2 Historical contributions to cumulative net anthropogenic CO₂ emissions between 1850 and 2019 vary substantially across regions in terms of total magnitude, but also in terms of contributions to CO₂-FFI (1650 +/- 73 GtCO₂-eq) and net CO₂-LULUCF (760 +/- 220 GtCO₂-eq) emissions.[FOOTNOTE 19] Globally, the major share of cumulative CO₂-FFI emissions is concentrated in a few regions, while cumulative CO₂-LULUCF [FOOTNOTE 9] emissions are concentrated in other regions. LDCs contributed less than 0.4% of historical cumulative CO₂-FFI emissions between 1850 and 2019, while SIDS contributed 0.5%. (*high confidence*) (Figure SPM.2) {Figure 2.10, 2.2, TS.3, Figure 2.7}

FOOTNOTE 9: Global databases make different choices about which emissions and removals occurring on land are considered anthropogenic. Currently, net CO₂ fluxes from land reported by global book-keeping models used here are estimated to be about ~5.5 GtCO₂ yr⁻¹ higher than the aggregate global net emissions based on national GHG inventories. This difference, which has been considered in the literature, mainly reflects differences in how anthropogenic forest sinks and areas of managed land are defined. Other reasons for this difference, which are more difficult to quantify, can arise from the limited representation of land management in global models and varying levels of accuracy and completeness of estimated LULUCF fluxes in national GHG inventories. Neither method is inherently preferable. Even when the same methodological approach is applied, the large uncertainty of CO₂-LULUCF emissions can lead to substantial revisions to estimated emissions. {Cross-Chapter Box 3 in Chapter 3, 7.2, SRCCL SPM A.3.3}

FOOTNOTE 19: For consistency with WGI, historical cumulative CO₂ emissions from 1850-2019 are reported using 68% confidence intervals.

B.3.3 In 2019, around 48% of the global population lives in countries emitting on average more than 6t CO₂-eq per capita, excluding CO₂-LULUCF. 35% live in countries emitting more than 9 tCO₂-eq per capita. Another 41% live in countries emitting less than 3 tCO₂-eq per capita. A substantial share of the population in these low emitting countries lack access to modern energy services (FOOTNOTE 20). Eradicating extreme poverty, energy poverty, and providing decent living standards (FOOTNOTE 21) to all in these regions in the context of achieving sustainable development objectives, in the near-term, can be achieved without significant global emissions growth. (*high confidence*) (Figure SPM.2) {Figure 1.2, 2.2, 2.4, 2.6, 3.7, 4.2, 6.7, Figure TS.4, Figure TS.5}

FOOTNOTE 20: In this report, access to modern energy services is defined as access to clean, reliable and affordable energy services for cooking and heating, lighting, communications, and productive uses (See Annex I: Glossary)

FOOTNOTE 21: In this report, decent living standards are defined as a set of minimum material requirements essential for achieving basic human well-being, including nutrition, shelter, basic living conditions, clothing, health care, education, and mobility. (See 5.1)

B.3.4 Globally, the 10% of households with the highest per capita emissions contribute 34-45% of global consumption-based household GHG emissions [FOOTNOTE 22], while the middle 40% contribute 40-53%, and the bottom 50% contribute 13-15%. (*high confidence*) {2.6, Figure 2.25}

FOOTNOTE 22: Consumption-based emissions refer to emissions released to the atmosphere to generate the goods and services consumed by a certain entity (e.g., a person, firm, country, or region).

The bottom 50% of emitters spend less than USD3PPP per capita per day. The top 10% of emitters (an open-ended category) spend more than USD23PPP per capita per day. The wide range of estimates for the contribution of the top 10% result from the wide range of spending in this category and differing methods in the assessed literature. {Annex I: Glossary; 2.6}

B.3.5 At least 18 countries have sustained production-based GHG and consumption-based CO₂ emission reductions for longer than 10 years. Reductions were linked to energy supply decarbonisation, energy efficiency gains, and energy demand reduction, which resulted from both policies and changes in economic structure. Some countries have reduced production-based GHG emissions by a third or more since peaking, and some have achieved several years of consecutive reduction rates of around 4 %/yr, comparable to global reductions in scenarios limiting warming to 2°C (>67%) or lower. These reductions have only partly offset global emissions growth. (*high confidence*) (Figure SPM.2) {Figure TS.4, 2.2, 1.3.2}