

Headline Statements from the Summary for Policymakers

4 April 2022 (subject to final copy-editing)

B. Recent developments and current trends

- B.1** Total net anthropogenic GHG emissions⁶ 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*)

[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*)
- B.3** Regional contributions¹⁷ 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*)

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

- B.4** The unit costs of several low-emission technologies have fallen continuously since 2010. Innovation policy packages have enabled these cost reductions and supported global adoption. Both tailored policies and comprehensive policies addressing innovation systems have helped overcome the distributional, environmental and social impacts potentially associated with global diffusion of low-emission technologies. Innovation has lagged in developing countries due to weaker enabling conditions. Digitalisation can enable emission reductions, but can have adverse side-effects unless appropriately governed. (*high confidence*)

- B.5** There has been a consistent expansion of policies and laws addressing mitigation since AR5. This has led to the avoidance of emissions that would otherwise have occurred and increased investment in low-GHG technologies and infrastructure. Policy coverage of emissions is uneven across sectors. Progress on the alignment of financial flows towards the goals of the Paris Agreement remains slow and tracked climate finance flows are distributed unevenly across regions and sectors. (*high confidence*)
- B.6** Global GHG emissions in 2030 associated with the implementation of nationally determined contributions (NDCs) announced prior to COP26²⁴ would make it likely that warming will exceed 1.5°C during the 21st century.²⁵ Likely limiting warming to below 2°C would then rely on a rapid acceleration of mitigation efforts after 2030. Policies implemented by the end of 2020²⁶ are projected to result in higher global GHG emissions than those implied by NDCs. (*high confidence*)
- FOOTNOTE 24: NDCs announced prior to COP26 refer to the most recent nationally determined contributions submitted to the UNFCCC up to the literature cut-off date of this report, 11 October 2021, and revised NDCs announced by China, Japan and the Republic of Korea prior to October 2021 but only submitted thereafter. 25 NDC updates were submitted between 12 October 2021 and prior to the start of COP26.
- FOOTNOTE 25: This implies that mitigation after 2030 can no longer establish a pathway with less than 67% probability to exceed 1.5°C during the 21st century, a defining feature of the class of pathways that limit warming to 1.5°C (>50%) with no or limited overshoot assessed in this report (Category C1 in Table SPM.1). These pathways limit warming to 1.6°C or lower throughout the 21st century with a 50% likelihood.
- FOOTNOTE 26: The policy cut-off date in studies used to project GHG emissions of “policies implemented by the end of 2020” varies between July 2019 and November 2020. {Table 4.2}
- B.7** Projected cumulative future CO₂ emissions over the lifetime of existing and currently planned fossil fuel infrastructure without additional abatement exceed the total cumulative net CO₂ emissions in pathways that limit warming to 1.5°C (>50%) with no or limited overshoot. They are approximately equal to total cumulative net CO₂ emissions in pathways that limit warming to 2°C (>67%). (*high confidence*)

C. System transformations to limit global warming

- C.1** Global GHG emissions are projected to peak between 2020 and at the latest before 2025 in global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot and in those that limit warming to 2°C (>67%) and assume immediate action. [Table SPM footnote [#9],³⁸ In both types of modelled pathways, rapid and deep GHG emissions reductions follow throughout 2030, 2040 and 2050 (*high confidence*). Without a strengthening of policies beyond those that are implemented by the end of 2020, GHG emissions are projected to rise beyond 2025, leading to a median global warming of 3.2 [2.2 to 3.5] °C by 2100^{39, 40} (*medium confidence*).

FOOTNOTE 38: All reported warming levels are relative to the period 1850–1900. If not otherwise specified, ‘pathways’ always refer to pathways computed with a model. Immediate action in the pathways refers to the adoption of climate policies between 2020 and at latest 2025 intended to limit global warming at a given level.

FOOTNOTE 39: Long-term warming is calculated from all modelled pathways assuming mitigation efforts consistent with national policies that were implemented by the end of 2020 (scenarios that

fall into policy category P1b of Chapter 3) and that pass through the 2030 GHG emissions ranges of such pathways assessed in Chapter 4 Footnote [#20]. {3.2, Table 4.2}

FOOTNOTE 40: Warming estimates refer to the 50th and [5th–95th] percentile across the modelled pathways and the median temperature change estimate of the probabilistic WG I climate model emulators[Footnote 1] (Table SPM1).

- C.2** Global net zero CO₂ emissions are reached in the early 2050s in modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, and around the early 2070s in modelled pathways that limit warming to 2°C (>67%). Many of these pathways continue to net negative CO₂ emissions after the point of net zero. These pathways also include deep reductions in other GHG emissions. The level of peak warming depends on cumulative CO₂ emissions until the time of net zero CO₂ and the change in non-CO₂ climate forcings by the time of peaking. Deep GHG emissions reductions by 2030 and 2040, particularly reductions of methane emissions, lower peak warming, reduce the likelihood of overshooting warming limits and lead to less reliance on net negative CO₂ emissions that reverse warming in the latter half of the century. Reaching and sustaining global net zero GHG emissions results in a gradual decline in warming. (*high confidence*)
- C.3** All global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, and those that limit warming to 2°C (>67%) involve rapid and deep and in most cases immediate GHG emission reductions in all sectors. Modelled mitigation strategies to achieve these reductions include transitioning from fossil fuels without CCS to very low- or zero-carbon energy sources, such as renewables or fossil fuels with CCS, demand side measures and improving efficiency, reducing non-CO₂ emissions, and deploying carbon dioxide removal (CDR) methods to counterbalance residual GHG emissions. Illustrative Mitigation Pathways (IMPs) show different combinations of sectoral mitigation strategies consistent with a given warming level. (*high confidence*)
- C.4** Reducing GHG emissions across the full energy sector requires major transitions, including a substantial reduction in overall fossil fuel use, the deployment of low-emission energy sources, switching to alternative energy carriers, and energy efficiency and conservation. The continued installation of unabated fossil fuel⁵⁵ infrastructure will 'lock-in' GHG emissions. (*high confidence*)
- FOOTNOTE 55: In this context, 'unabated fossil fuels' refers to fossil fuels produced and used without interventions that substantially reduce the amount of GHG emitted throughout the life-cycle; for example, capturing 90% or more from power plants, or 50-80% of fugitive methane emissions from energy supply.
- C.5** Net-zero CO₂ emissions from the industrial sector are challenging but possible. Reducing industry emissions will entail coordinated action throughout value chains to promote all mitigation options, including demand management, energy and materials efficiency, circular material flows, as well as abatement technologies and transformational changes in production processes. Progressing towards net zero GHG emissions from industry will be enabled by the adoption of new production processes using low and zero GHG electricity, hydrogen, fuels, and carbon management. (*high confidence*)
- C.6** Urban areas can create opportunities to increase resource efficiency and significantly reduce GHG emissions through the systemic transition of infrastructure and urban form through low-emission development pathways towards net-zero emissions. Ambitious mitigation efforts for established, rapidly growing and emerging cities will encompass 1) reducing or changing energy and material consumption, 2) electrification, and 3) enhancing carbon uptake and storage in the urban environment. Cities can achieve net-zero emissions, but only if emissions are reduced within and

outside of their administrative boundaries through supply chains, which will have beneficial cascading effects across other sectors. (*very high confidence*)

- C.7** In modelled global scenarios, existing buildings, if retrofitted, and buildings yet to be built, are projected to approach net zero GHG emissions in 2050 if policy packages, which combine ambitious sufficiency, efficiency, and renewable energy measures, are effectively implemented and barriers to decarbonisation are removed. Low ambitious policies increase the risk of lock-in buildings in carbon for decades while well-designed and effectively implemented mitigation interventions, in both new buildings and existing ones if retrofitted, have significant potential to contribute to achieving SDGs in all regions while adapting buildings to future climate. (*high confidence*)
- C.8** Demand-side options and low-GHG emissions technologies can reduce transport sector emissions in developed countries and limit emissions growth in developing countries (*high confidence*). Demand-focused interventions can reduce demand for all transport services and support the shift to more energy efficient transport modes (*medium confidence*). Electric vehicles powered by low emissions electricity offer the largest decarbonisation potential for land-based transport, on a life cycle basis (*high confidence*). Sustainable biofuels can offer additional mitigation benefits in land-based transport in the short and medium term (*medium confidence*). Sustainable biofuels, low emissions hydrogen, and derivatives (including synthetic fuels) can support mitigation of CO₂ emissions from shipping, aviation, and heavy-duty land transport but require production process improvements and cost reductions (*medium confidence*). Many mitigation strategies in the transport sector would have various co-benefits, including air quality improvements, health benefits, equitable access to transportation services, reduced congestion, and reduced material demand (*high confidence*).
- C.9** AFOLU mitigation options, when sustainably implemented, can deliver large-scale GHG emission reductions and enhanced removals, but cannot fully compensate for delayed action in other sectors. In addition, sustainably sourced agricultural and forest products can be used instead of more GHG intensive products in other sectors. Barriers to implementation and trade-offs may result from the impacts of climate change, competing demands on land, conflicts with food security and livelihoods, the complexity of land ownership and management systems, and cultural aspects. There are many country-specific opportunities to provide co-benefits (such as biodiversity conservation, ecosystem services, and livelihoods) and avoid risks (for example, through adaptation to climate change). (*high confidence*)
- C.10** Demand-side mitigation encompasses changes in infrastructure use, end-use technology adoption, and socio-cultural and behavioural change. Demand-side measures and new ways of end-use service provision can reduce global GHG emissions in end use sectors by 40-70% by 2050 compared to baseline scenarios, while some regions and socioeconomic groups require additional energy and resources. Demand side mitigation response options are consistent with improving basic wellbeing for all. (*high confidence*)
- C.11** The deployment of CDR to counterbalance hard-to-abate residual emissions is unavoidable if net zero CO₂ or GHG emissions are to be achieved. The scale and timing of deployment will depend on the trajectories of gross emission reductions in different sectors. Upscaling the deployment of CDR depends on developing effective approaches to address feasibility and sustainability constraints especially at large scales. (*high confidence*)
- C.12** Mitigation options costing USD100 tCO₂-eq-1 or less could reduce global GHG emissions by at least half the 2019 level by 2030 (*high confidence*). Global GDP continues to grow in modelled

pathways⁶⁵ but, without accounting for the economic benefits of mitigation action from avoided damages from climate change nor from reduced adaptation costs, it is a few percent lower in 2050 compared to pathways without mitigation beyond current policies. The global economic benefit of limiting warming to 2°C is reported to exceed the cost of mitigation in most of the assessed literature. (*medium confidence*)

FOOTNOTE 65: In modelled pathways that limit warming to 2°C (>67%) or lower.

D. *Linkages between mitigation, adaptation, and sustainable development*

- D.1** Accelerated and equitable climate action in mitigating, and adapting to, climate change impacts is critical to sustainable development. Climate change actions can also result in some trade-offs. The trade-offs of individual options could be managed through policy design. The Sustainable Development Goals (SDGs) adopted under the UN 2030 Agenda for Sustainable Development can be used as a basis for evaluating climate action in the context of sustainable development. (*high confidence*)
- D.2** There is a strong link between sustainable development, vulnerability and climate risks. Limited economic, social and institutional resources often result in high vulnerability and low adaptive capacity, especially in developing countries (*medium confidence*). Several response options deliver both mitigation and adaptation outcomes, especially in human settlements, land management, and in relation to ecosystems. However, land and aquatic ecosystems can be adversely affected by some mitigation actions, depending on their implementation (*medium confidence*). Coordinated cross-sectoral policies and planning can maximise synergies and avoid or reduce trade-offs between mitigation and adaptation (*high confidence*).
- D.3** Enhanced mitigation and broader action to shift development pathways towards sustainability will have distributional consequences within and between countries. Attention to equity and broad and meaningful participation of all relevant actors in decision-making at all scales can build social trust, and deepen and widen support for transformative changes. (*high confidence*)

E. *Strengthening the response*

- E.1** There are mitigation options which are feasible⁷² to deploy at scale in the near term. Feasibility differs across sectors and regions, and according to capacities and the speed and scale of implementation. Barriers to feasibility would need to be reduced or removed, and enabling conditions⁷³ strengthened to deploy mitigation options at scale. These barriers and enablers include geophysical, environmental-ecological, technological, and economic factors, and especially institutional and socio-cultural factors. Strengthened near-term action beyond the NDCs (announced prior to UNFCCC COP26) can reduce and/or avoid long-term feasibility challenges of global modelled pathways that limit warming to 1.5 °C (>50%) with no or limited overshoot. (*high confidence*)

FOOTNOTE 72: In this report, the term 'feasibility' refers to the potential for a mitigation or adaptation option to be implemented. Factors influencing feasibility are context-dependent and may change over time. Feasibility depends on geophysical, environmental-ecological, technological, economic, socio-cultural and institutional factors that enable or constrain the implementation of an

option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened.

FOOTNOTE 73: In this report, the term 'enabling conditions' refers to conditions that enhance the feasibility of adaptation and mitigation options. Enabling conditions include finance, technological innovation, strengthening policy instruments, institutional capacity, multi-level governance and changes in human behaviour and lifestyles.

- E.2** In all countries, mitigation efforts embedded within the wider development context can increase the pace, depth and breadth of emissions reductions (*medium confidence*). Policies that shift development pathways towards sustainability can broaden the portfolio of available mitigation responses, and enable the pursuit of synergies with development objectives (*medium confidence*). Actions can be taken now to shift development pathways and accelerate mitigation and transformations across systems (*high confidence*).
- E.3** Climate governance, acting through laws, strategies and institutions, based on national circumstances, supports mitigation by providing frameworks through which diverse actors interact, and a basis for policy development and implementation (*medium confidence*). Climate governance is most effective when it integrates across multiple policy domains, helps realise synergies and minimize trade-offs, and connects national and sub-national policy-making levels (*high confidence*). Effective and equitable climate governance builds on engagement with civil society actors, political actors, businesses, youth, labour, media, Indigenous Peoples and local communities (*medium confidence*).
- E.4** Many regulatory and economic instruments have already been deployed successfully. Instrument design can help address equity and other objectives. These instruments could support deep emissions reductions and stimulate innovation if scaled up and applied more widely (*high confidence*). Policy packages that enable innovation and build capacity are better able to support a shift towards equitable low-emission futures than are individual policies (*high confidence*). Economy-wide packages, consistent with national circumstances, can meet short-term economic goals while reducing emissions and shifting development pathways towards sustainability (*medium confidence*).
- E.5** Tracked financial flows fall short of the levels needed to achieve mitigation goals across all sectors and regions. The challenge of closing gaps is largest in developing countries as a whole. Scaling up mitigation financial flows can be supported by clear policy choices and signals from governments and the international community. (*high confidence*) Accelerated international financial cooperation is a critical enabler of low-GHG and just transitions, and can address inequities in access to finance and the costs of, and vulnerability to, the impacts of climate change (*high confidence*).
- E.6** International cooperation is a critical enabler for achieving ambitious climate change mitigation goals. The UNFCCC, Kyoto Protocol, and Paris Agreement are supporting rising levels of national ambition and encouraging development and implementation of climate policies, although gaps remain. Partnerships, agreements, institutions and initiatives operating at the sub-global and sectoral levels and engaging multiple actors are emerging, with mixed levels of effectiveness. (*high confidence*)