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Climate Change 2022

Mitigation of Climate Change



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 Sixth Assessment Report
of the Intergovernmental Panel on Climate Change**

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Foreword and Preface

Foreword

Climate Change 2022: Mitigation of Climate Change is the third part of the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) and was prepared by its Working Group III. The volume provides an updated global assessment of current and projected emissions from all sources and sectors, mitigation options that reduce emissions or remove greenhouse gases from the atmosphere, and progress towards meeting climate ambitions. It assesses what is required to achieve net zero emissions as pledged by many countries.

This report shows that greenhouse gas emissions over the last decade are at the highest levels in human history. It shows that urgent action is needed. Unless there are immediate and deep emissions reductions across all sectors, limiting global warming to 1.5°C will be beyond reach. Global greenhouse gas emissions implied by Nationally Determined Contributions announced prior to COP26 make it likely that warming will exceed 1.5°C and will also make it harder to limit warming to below 2°C.

But there are positive signs and increased evidence of climate action. Options are available now in every sector that can at least halve emissions by 2030. Some countries have already achieved a steady decrease in emissions consistent with limiting warming to 2°C. Costs for some forms of renewable energy have fallen, use of renewables continues to rise and, in some countries and regions, electricity systems are already predominantly powered by renewables.

This IPCC report highlights for the first time the social and demand-side aspects of climate mitigation. As long as the necessary policies, infrastructure and technologies are in place, changes to lifestyles and behaviour have the potential for large reductions in global greenhouse gas emissions and, at the same time, lead to improved wellbeing.

The report calls attention to the deep links between climate mitigation and sustainable development. It draws attention to the way that climate action is intimately connected to addressing the nature crisis. Attention to equity and just transitions can support deeper ambition for accelerated climate action.

The findings in this report have considerably enhanced our understanding of available mitigation pathways. The timing of this report is critical. It provides crucial information that informs the first Global Stocktake under the Paris Agreement. It demands the urgent attention of policymakers and the general public.



Petteri Taalas
Secretary-General
World Meteorological Organization

As an intergovernmental body jointly established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the IPCC has successfully provided policymakers with the most authoritative and objective scientific and technical assessments, which are policy relevant without being policy prescriptive. Beginning in 1990, this series of IPCC Assessment Reports, Special Reports, Technical Papers, Methodology Reports and other products have become standard works of reference.

This Working Group III assessment was made possible thanks to the commitment and dedication of many hundreds of experts, representing a wide range of regions and scientific disciplines. WMO and UNEP are proud that so many of the experts belong to their communities and networks.

We express our deep gratitude to all authors, review editors and expert reviewers for devoting their knowledge, expertise and time. We note the particular challenges presented by the COVID-19 pandemic and the burdens placed on experts. We would like to thank the staff of the Working Group III Technical Support Unit and the IPCC Secretariat for their dedication.

We are also thankful to the governments that supported their scientists' participation in developing this report and that contributed to the IPCC Trust Fund to provide for the essential participation of experts from developing countries and countries with economies in transition.

We would like to express our appreciation to the government of Ethiopia for hosting the scoping meeting for the IPCC's Sixth Assessment Report, to the governments of the United Kingdom of Great Britain and Northern Ireland, India, Ecuador and Italy for hosting drafting sessions for the Working Group III contribution. The latter two meetings were held in a virtual format due to the COVID-19 pandemic. We also express our thanks to the government of the United Kingdom for hosting the Fourteenth Session of Working Group III for approval of the Working Group III Report. The generous financial support by the government of the United Kingdom, and the hosting of the Working Group III Technical Support Unit by Imperial College London (United Kingdom) and Ahmedabad University (India), is gratefully acknowledged.

We would particularly like to thank Dr. Hoesung Lee, Chairman of the IPCC, for his direction and guidance of the IPCC and we express our deep gratitude to Professor Priyadarshi R. Shukla and Professor Jim Skea, the Co-Chairs of Working Group III, for their tireless leadership throughout the development and production of this report.



Inger Andersen
Executive Director
United Nations Environment Programme

Preface

The Working Group III (WG III) contribution to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) provides a comprehensive and transparent assessment of the scientific literature on climate change mitigation. It builds upon the WG III contribution to the IPCC's Fifth Assessment Report (AR5) in 2014, the WG I and WG II contributions to the AR6, and the three AR6 Special Reports: *Global Warming of 1.5°C*; *Climate Change and Land*; and *The Ocean and Cryosphere in a Changing Climate*.

The report assesses progress in climate change mitigation and options for reducing emissions and enhancing sinks. It evaluates the societal implications of mitigation actions, without recommending any specific options.

Scope of the Report

The scoping of the WG III contribution to AR6 was driven by three guiding principles: to achieve a better synthesis between higher-level whole system and grounded bottom-up insights into technologies and other approaches for reducing emissions; to make wider use of social science disciplines, especially for gaining insight into issues related to lifestyle, behaviour, consumption and socio-technical transitions; and to link climate change mitigation better to other agreed policy goals both nationally and internationally.

The core of the report remains, as in AR5, a set of chapters devoted to different sectors, broadly aligned with the categorisation used in the IPCC Guidelines for National Greenhouse Gas Inventories. These chapters cover emission trends and drivers, mitigation costs and potentials, regional specificities, and sector specific barriers, policies, financing and enabling conditions. A systems level perspective was followed where appropriate. A cross-sectoral perspectives chapter integrates findings from the sectoral chapters and assesses approaches falling outside the scope of individual sectors.

As in the AR5, there is a chapter on recent trends and drivers, with the scope expanded to cover historic emissions and recent policy developments. Following the pattern established in the WG III AR5 report, and the Special Report on Global Warming of 1.5°C, this report assesses published emission scenarios with a 21st century perspective. Modelled emission scenarios are categorised according to climate outcomes, allowing a handshake with the WG I assessment. To meet the goal of linking top-down and bottom-up insights, the report includes an additional pathways chapter that provides a mid-century perspective, focussing on national and regional scales and the alignment between development pathways and mitigation actions.

As in the AR5, this report addresses mitigation enablers such as international cooperation, finance and investment, and policies and institutions, with a greater emphasis placed on the role of institutions than in the AR5. A new chapter is dedicated to the assessment of innovation systems, technology development and technology

transfer. A further novelty is a chapter that assesses the literature on human behaviour, lifestyle and culture, and its implications for mitigation action. This chapter touches on patterns of development and human well-being, and circular and sharing economy concepts. It brings a wide range of disciplines, notably from the social sciences, within the scope of the WG III assessment.

Linkages with development and specifically the Sustainable Development Goals (SDGs) permeate the WG III report. This framing is set up in Chapter 1, and the threads are drawn together in the final chapter where linkages between mitigation and the SDGs are systematically assessed.

The AR6 has benefited from close and unprecedented collaboration between the three IPCC WGs: with WG I on scenarios and with WG II on urban systems, land use and development pathways. This collaboration is manifested in a number of Cross-Working Group boxes covering topics such as the economic benefits from avoided impacts along mitigation pathways, climate change and urban areas, mitigation and adaptation through the bioeconomy, and solar radiation modification.

Structure of the Report

This report consists of a Summary for Policymakers, a Technical Summary, 17 Chapters, six Annexes, and Index, as well as online Supplementary Material to chapters.

Chapters 1 (Introduction and framing) and 17 (Accelerating the transition in the context of sustainable development), the first and final chapters of the report, set climate change mitigation in the context of sustainable development. Chapter 1 sets out the evolving policy landscape for climate mitigation, provides the reader with the framing of, and context for, the report, and highlights key concepts. Chapter 17 adopts an integrative perspective on sustainable development and climate change responses, identifying synergies and trade-offs, and explores joint responses to climate change and sustainable development challenges.

Chapters 2–4 take a high-level view of trends and future pathways using three different time frames. Chapter 2 (Emissions trends and drivers) covers historic and current emission trends and socio-economic and demographic drivers of emissions. It also maps developments in technologies and policies since the AR5. Chapter 3 (Mitigation pathways compatible with long-term goals) assesses modelled emission pathways compatible with the Paris Agreement and higher warming levels. It addresses socio-cultural-techno-economic assumptions, technological and behavioural aspects of mitigation pathways, and links to adaptation and sustainable development. Chapter 4 (Mitigation and development pathways in the near- to mid-term) takes a mid-century perspective, considering national, regional and international scales and the implications

of mitigation for national development objectives including employment, competitiveness, poverty eradication and the SDGs. Annex III (Scenarios and modelling methods) provides methodological background to Chapters 3 and 4.

Chapter 5 (Demand, services and social aspects of mitigation), a new chapter in AR6, explores how mitigation interacts with meeting human needs and access to services. It explores, *inter alia*: sustainable production and consumption; patterns of development and indicators of wellbeing; the role of culture, social norms, practices and behaviour changes; the sharing economy and circular economy; and policies facilitating behavioural and lifestyle change.

Chapters 6–12 (Energy systems; Agriculture, Forestry, and Other Land Uses (AFOLU); Urban systems and other settlements; Buildings; Transport; Industry; Cross-sectoral perspectives) assess the potential for emissions reductions in specific systems and sectors, taking into account trends in emissions and their key drivers, global and regional costs and potentials, links to climate adaptation and associated risks and co-benefits, and sector specific barriers, policies, financing and enabling conditions. Specificities include fugitive emissions and carbon capture and storage (Energy), provision of food, feed, fibre, wood, biomass for energy and other ecosystem services (AFOLU), demographic changes and urban form (Urban systems and other settlements), mitigation strategies including efficiency, sufficiency and renewables (Buildings), access to mobility (Transport), and resource efficiency (Industry). Chapter 12 (Cross-sectoral perspectives) synthesises costs and potentials, and co-benefits and trade-offs, across sectors; it also addresses cross-cutting approaches such as carbon dioxide removal and mitigation opportunities in the food system.

Chapters 13–16 address enabling conditions for mitigation action. Chapter 13 (National and sub-national policies and institutions) provides insights from national and subnational plans and strategies, including trends in legislation and institutions. Chapter 14 (International cooperation) assesses international cooperation and institutions, including linkages with non-climate organisations and processes, international sectoral agreements, and institutions for finance and investment and capacity building. Chapter 15 (Investment and finance) assesses scenarios of, and needs for, mitigation investment and financial flows, and the means of mobilising climate finance at the national and sub-national levels. Chapter 16 (Innovation, technology development and transfer) examines the role of innovation, technology development, diffusion and transfer in contributing to sustainable development and the aims of the Paris Agreement. It addresses specific challenges in emerging economies and least developed countries.

The Assessment Process

This WG III contribution to the AR6 has been prepared in accordance with IPCC rules and procedures. A scoping meeting was held in May 2017 and the outlines for the contributions of the three WGs were approved at the 46th Session of the Panel in September 2017.

Governments and IPCC observer organisations nominated experts for the author teams. The team of 199 Coordinating Lead Authors and Lead Authors, plus 38 Review Editors, selected by the WG III Bureau, was accepted at the 55th Session of the IPCC Bureau in January 2018. More than 350 Contributing Authors provided text for the author teams.

Drafts were subject to two rounds of formal review and revision followed by a final round of government comments on the Summary for Policymakers. More than 59,000 written comments were submitted by more than 1,600 expert reviewers and 42 governments. For each chapter, the review process was monitored by Review Editors to ensure that all comments received appropriate consideration.

During the review periods and in the run-up to the approval session, webinars were held with governments and two of the UNFCCC non-governmental organisation (NGO) constituencies, the Business and Industry NGOs (BINGOs), and the Environmental NGOs (ENGOS). These informal webinars offered an opportunity for authors to present draft material to IPCC audiences and to receive additional feedback.

The Report was accepted by the Panel at its 56th Session. The Summary for Policymakers was approved line-by-line and the underlying chapters were accepted at the 14th Session of IPCC WG III from 21 March – 4 April 2022, hosted virtually by the United Kingdom of Great Britain and Northern Ireland (UK).

Acknowledgements

The report was made possible thanks to the expertise, hard work and commitment to excellence shown by Coordinating Lead Authors and Lead Authors, with inputs from many Contributing Authors. Their efforts and stamina are particularly commendable given the additional demands and stresses imposed by virtual working as a consequence of the COVID pandemic.

We gratefully acknowledge the support of the Chapter Scientists, who worked tirelessly alongside the authors to deliver their chapters to the highest possible standards. Their time, dedication and hard work is greatly appreciated.

We would like to express our appreciation to the Government and Expert Reviewers for the time and energy they invested to provide constructive and useful comments on the draft reports. Our Review Editors were also critical in the AR6 process, helping author teams to process comments, and assuring an objective discussion of relevant issues.

We wish to thank the governments and other institutions for generous support which enabled the authors, Review Editors and Government and Expert Reviewers to participate.

We would like to thank the Vice-Chairs of the WG III Bureau, who provided invaluable scientific input and thoughtful advice throughout the AR6 process: Amjad Abdulla, Carlo Carraro, Diriba Korecha Dadi, Ramón Pichs-Madruga, Nagmeldin G.E. Mahmoud, Andy Reisinger and Diana Ürge-Vorsatz. Specific thanks are due to Andy Reisinger, who together with the Co-Chairs acted as an editor of the Summary for Policymakers, and to Ramón Pichs-Madruga and Diana Ürge-Vorsatz, who took on roles of editors of the Technical Summary.

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We acknowledge support from countries hosting WG III Lead Author Meetings (LAMs): the UK for hosting the first LAM in Edinburgh (March 2019); India for hosting the second LAM in New Delhi (September 2019); Ecuador for hosting the third LAM virtually (April 2020); and Italy for hosting the fourth LAM, also held virtually (April 2021). We thank the government of Ethiopia for hosting the Scoping Meeting for the report in Addis Ababa (May 2017).

We are especially grateful for the support of the UK government, in particular the Department of Business, Energy and Industrial Strategy (BEIS) and the Engineering and Physical Sciences Research Council (EPSRC), for funding the WG III Technical Support Unit (TSU). Jolene Cook, Eleanor Webster, Rhian Rees-Owen, Sarah Honour, Cathy Johnson, Julie Maclean, Alice Montgomery, Caroline Prescott, and Andrew Russell at BEIS, and Jim Fleming, Kathryn Magnay, Strachan McCormick, Kate Bowman and Jasmine Cain at EPSRC were always ready to dedicate time and energy to the needs of the team. BEIS also organised the venue hosting the core team for the 14th Session of IPCC WG III.

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Sincerely,



Jim Skea
Co-Chair Working Group III



Priyadarshi R. Shukla
Co-Chair Working Group III

In memoriam

Cristóbal Díaz Morejón
(1949–2021)

Lead Author of Chapter 17 on Accelerating the transition in the context of sustainable development

Cristóbal Díaz Morejón was an internationally renowned expert across a range of environmental disciplines. Over the course of a busy and successful career he led projects on the salinity of soils, water resource management, environmental strategy, desertification and droughts, and energy efficiency, amongst others. He represented Cuba in many international meetings on water resources and sustainable development. In 1994 he was awarded a Medal by the Academy of Sciences of Cuba on its 30th Anniversary, and in 2004, the “Juan Tomas Roig” Medal for 25 years dedicated to research. A contributor to IPCC reports since 2004, he was an intelligent, knowledgeable, dedicated and kind colleague, and will be sorely missed.

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