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

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Contents

Foreword and Preface

Foreword

This IPCC Special Report on Global Warming of 1.5°C was formally approved by the world's governments in 2018 – the year of IPCC's 30th anniversary celebrations.

During its three decades of existence, the IPCC has shed light on climate change, contributing to the understanding of its causes and consequences and the options for risk management through adaptation and mitigation. In these three decades, global warming has continued unabated and we have witnessed an acceleration in sea-level rise. Emissions of greenhouse gases due to human activities, the root cause of global warming, continue to increase, year after year.

Five years ago, the IPCC's Fifth Assessment Report provided the scientific input into the Paris Agreement, which aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

Many countries considered that a level of global warming close to 2°C would not be safe and, at that time, there was only limited knowledge about the implications of a level of 1.5°C of warming for climate-related risks and in terms of the scale of mitigation ambition and its feasibility. Parties to the Paris Agreement therefore invited the IPCC to assess the impacts of global warming of 1.5°C above pre-industrial levels and the related emissions pathways that would achieve this enhanced global ambition.

At the start of the Sixth Assessment cycle, governments, in a plenary IPCC session, decided to prepare three special reports, including this one, and expanded the scope of this special report by framing the assessment in the context of sustainable development and efforts to eradicate poverty.

Sustainable development goals provide a new framework to consider climate action within the multiple dimensions of sustainability. This report is innovative in multiple ways. It shows the importance of integration across the traditional IPCC working groups and across disciplines within each chapter. Transitions, integrating adaptation and mitigation for each sector, are explored within six dimensions of feasibility, showing both low hanging fruits and barriers to overcome. It also provides scientific guidance on strategies to embed climate action within development strategies, and how to optimize choices that maximize benefits for multiple sustainable development dimensions and implement ethical and just transitions.

In his address to the UN General Assembly in 2018, Secretary-General António Guterres quoted World Meteorological Organization (WMO) data showing that the past two decades have included eighteen of the twenty warmest years since record-keeping began in 1850.

"Climate change is moving faster than we are," said Secretary-General Guterres. *"We must listen to the Earth's best scientists,"* he added.

One month later the IPCC presented the Special Report on Global Warming of 1.5°C, based on the assessment of around 6,000 peer-review publications, most of them published in the last few years. This Special Report confirms that climate change is already affecting people, ecosystems and livelihoods all around the world. It shows that limiting warming to 1.5°C is possible within the laws of chemistry and physics but would require unprecedented transitions in all aspects of society. It finds that there are clear benefits to keeping warming to

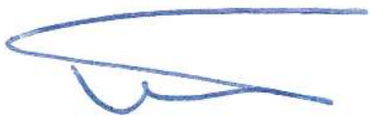
1.5°C rather than 2°C or higher. Every bit of warming matters. And it shows that limiting warming to 1.5°C can go hand in hand with achieving other global goals such as the Sustainable Development Agenda. Every year matters and every choice matters.

This Special Report also shows that recent trends in emissions and the level of international ambition indicated by nationally determined contributions, within the Paris Agreement, deviate from a track consistent with limiting warming to well below 2°C. Without increased and urgent mitigation ambition in the coming years, leading to a sharp decline in greenhouse gas emissions by 2030, global warming will surpass 1.5°C in the following decades, leading to irreversible loss of the most fragile ecosystems, and crisis after crisis for the most vulnerable people and societies.

The Special Report on Global Warming of 1.5°C supports efforts by the WMO and United Nations Environment Programme for a comprehensive assessment of our understanding of climate change to help step up action to respond to climate change, achieve climate-resilient development and foster an integrated approach to the provision of climate services at all scales of governance.

The IPCC worked in record time to deliver this report for the 24th Conference of Parties (COP24) to the United Nations Framework Convention on Climate Change (UNFCCC) and the Talanoa Dialogue. We would like to thank Hoesung Lee, Chair of the IPCC, for his leadership and guidance in the preparation of this Special Report. We commend the work undertaken by the authors of this Special Report and the many contributing authors and reviewers within a timeline of unprecedented severity; the leadership of the Co-Chairs of Working Groups I, II and III: Valérie Masson-Delmotte, Panmao Zhai, Hans-Otto Pörtner, Debra Roberts, Jim Skea and Priyadarshi R. Shukla; the oversight by the Bureau members of Working Groups I, II and III; and the implementation by the Technical Support Unit of Working Group I, supported by the Technical Support Units of Working Groups II and III. We are also grateful for the responsiveness of the international research community, who produced the knowledge assessed in the report, and thank the reviewers of the report for the thousands of comments that helped the authors strengthen the assessment.

Every bit of warming matters, every year matters, every choice matters



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Preface

This Special Report on 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, is the first publication in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6). The Report was jointly prepared by Working Groups I, II and III. It is the first IPCC Report to be collectively produced by all three Working Groups, symbolizing the new level of integration sought between Working Groups during AR6. The Working Group I Technical Support Unit has been responsible for the logistical and technical support for the preparation of the Special Report. The Special Report builds upon the IPCC's Fifth Assessment Report (AR5) released in 2013–2014 and on relevant research subsequently published in the scientific, technical and socio-economic literature. It has been prepared following IPCC principles and procedures, following AR5 guidance on calibrated language for communicating the degree of certainty in key findings. This Special Report is the first of three cross-Working Group Special Reports to be published in AR6, accompanying the three main Working Group Reports, the Synthesis Report and a Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Scope of the Report

In its decision on the adoption of the Paris Agreement, the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) at its 21st Session in Paris, France (30 November to 11 December 2015), invited the IPCC to provide a special report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. The Panel accepted the invitation and placed the Report in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

The broad scientific community has also responded to the UNFCCC invitation. New knowledge and literature relevant to the topics of this report have been produced and published worldwide. The Special Report is an assessment of the relevant state of knowledge, based on the scientific and technical literature available and accepted for publication up to 15 May 2018. The Report draws on the findings of more than 6,000 published articles.

Structure of the Report

This report consists of a short Summary for Policymakers, a Technical Summary, five Chapters, and Annexes, as well as online chapter Supplementary Material.

Chapter 1 frames the context, knowledge base and assessment approaches used to understand the impacts of 1.5°C global warming above pre-industrial levels and related global greenhouse gas emission pathways, building on AR5, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. The chapter provides an update on the current state of the climate system including the current level of warming.

Chapter 2 assesses the literature on mitigation pathways that limit or return global mean warming to 1.5°C (relative to the pre-industrial base period 1850–1900). Key questions addressed are: What types of mitigation pathways have been developed that could be consistent with 1.5°C? What changes in emissions, energy and land use do they entail? What do they imply for climate policy and implementation, and what impacts do they have on sustainable development? This chapter focuses on geophysical dimensions of feasibility and the technological and economic enabling conditions.

Chapter 3 builds on findings of AR5 and assesses new scientific evidence of changes in the climate system and the associated impacts on natural and human systems, with a specific focus on the magnitude and pattern of risks for global warming of 1.5°C above the pre-industrial period. It explores impacts and risks for a range of natural and human systems, including adaptation options, with a focus on how risk levels change between today and worlds where global mean temperature increases by 1.5°C and 2°C above pre-industrial levels. The chapter also revisits major categories of risk (Reasons for Concern) based on the assessment of the new knowledge available since AR5.

Chapter 4 discusses how the global economy and socio-technical and socio-ecological systems can transition to 1.5°C-consistent pathways and adapt to global warming of 1.5°C. In the context of systemic transitions across energy, land, urban and industrial systems, the chapter assesses adaptation and mitigation options, including carbon dioxide removal (CDR) measures, as well as the enabling conditions that would facilitate implementing the rapid and far-reaching global response.

Finally, Chapter 5 takes sustainable development, poverty eradication and reducing inequalities as the starting point and focus for analysis. It considers the complex interplay between

sustainable development, including Sustainable Development Goals (SDGs) and climate actions related to a 1.5°C warmer world. The chapter also examines synergies and trade-offs of adaptation and mitigation options with sustainable development and the SDGs and offers insights into possible pathways, especially climate-resilient development pathways toward a 1.5°C warmer world.

The Process

The Special Report on 1.5°C of the IPCC AR6 has been prepared in accordance with the principles and procedures established by the IPCC and represents the combined efforts of leading experts in the field of climate change. A scoping meeting for the SR1.5°C was held in Geneva, Switzerland, in August 2016, and the final outline was approved by the Panel at its 44th Session in October 2016 in Bangkok, Thailand. Governments and IPCC observer organizations nominated 541 experts for the author team. The team of 74 Coordinating Lead Authors and Lead Authors plus 17 Review Editors were selected by the Working Group I, II and III Bureaux. In addition, 133 Contributing Authors were invited by chapter teams to provide technical information in the form of text, graphs or data for assessment. Report drafts prepared by the authors were subject to two rounds of formal review and revision followed by a final round of government comments on the Summary for Policymakers. The enthusiastic participation of the scientific community and governments to the review process resulted in 42,001 written review comments submitted by 796 individual expert reviewers and 65 governments.

The 17 Review Editors monitored the review process to ensure that all substantive review comments received appropriate consideration. The Summary for Policymakers was approved line-by-line at the joint meeting of Working Groups I, II and III; it and the underlying chapters were then accepted at the 48th Session of the IPCC from 01–06 October 2018 in Incheon, Republic of Korea.

Acknowledgements

We are very grateful for the expertise, rigour and dedication shown throughout by the volunteer Coordinating Lead Authors and Lead Authors, working across scientific disciplines in each chapter of the report, with essential help by the many Contributing Authors. The Review Editors have played a critical role in assisting the author teams and ensuring the integrity of the review process. We express our sincere appreciation to all the expert and government reviewers. A special thanks goes to the Chapter Scientists of this report who went above and beyond what was expected of them: Neville Ellis, Tania Guillén Bolaños, Daniel Huppmann, Kiane de Kleijne, Richard Millar and Chandni Singh.

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Our heartfelt thanks go to the hosts and organizers of the scoping meeting, the four Special Report on 1.5°C Lead Author Meetings and the 48th Session of the IPCC. We gratefully acknowledge the support from the host countries and institutions: World Meteorological Organization, Switzerland; Ministry of Foreign Affairs, and the National Institute for Space Research (INPE), Brazil; Met Office and the University of Exeter, the United Kingdom; Swedish Meteorological and Hydrological Institute (SMHI), Sweden; the Ministry of Environment Natural Resources Conservation and Tourism, the National Climate Change Committee in the Department of Meteorological Services and the Botswana Global Environmental Change Committee at the University of Botswana, Botswana; and Korea Meteorological Administration (KMA) and Incheon Metropolitan City, the Republic of Korea. The support provided by governments and institutions, as well as through contributions to the IPCC Trust Fund, is thankfully acknowledged as it enabled the participation of the author teams in the preparation of the Report. The efficient operation of the Working Group I Technical Support Unit was made possible by the generous financial support provided by the government of France and administrative and information technology support from the Université Paris Saclay (France), Institut Pierre Simon Laplace (IPSL) and the Laboratoire des Sciences du Climat et de l'Environnement (LSCE). We thank the Norwegian Environment Agency for supporting the preparation of the graphics for the Summary for Policymakers. We thank the UNEP Library, who supported authors throughout the drafting process by providing literature for the assessment.

We would also like to thank Abdalah Mokssit, Secretary of the IPCC, and the staff of the IPCC Secretariat: Kerstin Stendahl, Jonathan Lynn, Sophie Schlingemann, Judith Ewa, Mxolisi Shongwe, Jesbin Baidya, Werani Zabula, Nina Peeva, Joelle Fernandez, Annie Courtin, Laura Biagioni and Oksana Ekzarho. Thanks are due to Elhousseine Gouaini who served as the conference officer for the 48th Session of the IPCC.

Finally, our particular appreciation goes to the Working Group Technical Support Units whose tireless dedication, professionalism and enthusiasm led the production of this Special Report. This Report could not have been prepared without the commitment of members of the Working Group I Technical Support Unit, all new to the IPCC, who rose to the unprecedented Sixth Assessment Report challenge and were pivotal in all aspects of the preparation of the Report: Yang Chen, Sarah Connors, Melissa Gomis, Elisabeth Lonnoy, Robin Matthews, Wilfran Moufouma-Okia, Clotilde Péan, Roz Pidcock, Anna Pirani, Nicholas Reay, Tim Waterfield, and Xiao Zhou. Our warmest thanks go to the collegial and collaborative support provided by Marlies Craig, Andrew Okem, Jan Petzold, Melinda Tignor and Nora Weyer from the WGII Technical Support Unit and Bhushan Kankal, Suvadip Neogi and Joana Portugal Pereira from the WGIII Technical Support Unit. A special thanks goes to Kenny Coventry, Harmen Gudde, Irene Lorenzoni, and Stuart Jenkins for their support with the figures in the Summary for Policymakers, as well as Nigel Hawtin for graphical support of the Report. In addition, the following contributions are gratefully acknowledged: Jatinder Padda (copy edit), Melissa Dawes (copy edit), Marilyn Anderson (index), Vincent Grégoire (layout) and Sarah le Rouzic (intern).

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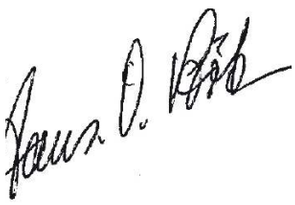

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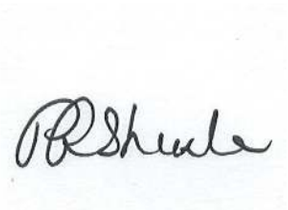

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Jim Skea
IPCC Working Group III Co-Chair

« Pour ce qui est de l'avenir, il ne s'agit pas de le prévoir, mais de le rendre possible. »

Antoine de Saint Exupéry, *Citadelle,* 1948