INTERGOVERNMENTAL PANEL ON climate change

AR6 Scoping Meeting
Addis Ababa, Ethiopia, 1 – 5 May 2017

AR6-SCOP/Doc. 2
(24.IV.2017)
ENGLISH ONLY

CHAIR'S VISION PAPER

(Submitted by the Chair of the IPCC)

IPCC Secretariat

c/o WMO • 7bis, Avenue de la Paix • C.P. 2300 • 1211 Geneva 2 • Switzerland
telephone : +41 (0) 22 730 8208 / 54 / 84 • fax : +41 (0) 22 730 8025 / 13 • email : IPCC-Sec@wmo.int • **www.ipcc.ch**

WMO UNEP

Table of Contents

Part C. Cross-cutting Issues

Scenarios and pathways (incl emission data, radiative forcing) I-II-III
Risk assessment I-II-III
Solar radiation management and greenhouse gas removal I-II-III
Air quality and short-lived climate pollutants I-II-III
Water and carbon in a changing climate I-II-III
Regional climate change and impacts, and options for a common atlas I-II
Integration of adaptation and mitigation responses II-III
Decision making II-III

Chair's Vision Paper (with inputs from IPCC Vice-Chairs and Co-Chairs of Working Groups and TFI)

A. Chair's Vision

Background

The IPCC is an organization with almost 30 years of unparalleled success in the production of "internationally co-ordinated scientific assessments of the magnitude, timing and potential environmental and socio-economic impact of climate change and realistic response strategies"[1]. With five comprehensive assessment reports and many special reports to its credit, which provide the global community with the most up-to-date understanding of human-induced climate change, it can be said the IPCC's work is recognized as the most authoritative source of knowledge on the subject. The credibility of the IPCC's work has undoubtedly contributed to the substantial increase of awareness of climate change globally on the part of all stakeholders, as well as to a deep reliance of the climate negotiations on the findings of the IPCC. Since the policy-relevance of the IPCC's assessments is the hallmark of its work, it is crucial for the IPCC to remain in sync with the shifting global technological, economic and social landscapes on which its work is based. For this, consideration of new knowledge is at the heart of the IPCC reports and will be of primary importance in the design of the Sixth Assessment Report (AR6) outline. At the start of the AR6 cycle, it is useful to reflect on the content of the possible future assessment in order to inform the scientific community and stimulate high quality of research needed on the physical, ecological, health, technical and socio-economic information to be assessed by the IPCC.

The last year and a half have been noteworthy for the leaps forward in terms of fusing economic growth with development and climate responsibility, marked by the adoption of the SDGs, the Addis Ababa Action Agenda to support their implementation, the Paris Agreement and its speedy entry into force. This series of actions clearly indicates that the global mindset is now solution-oriented, and it is particularly important for the IPCC to build its programme of work for the AR6 cycle in support of the UN Framework Convention on Climate Change and tuned to the global sustainable development agenda and priorities. In this regard, the role of improved understanding, which goes from progress in very basic science to applied aspects, encompassing a better understanding of sources of uncertainty, is important. Solution-focused information may also include improving the understanding of perception of climate change impacts and policies; assessing climate risk in relation to other economic and societal risks; assessing the risk profile of new technologies and investor rankings of these risks; risk and uncertainties that are most relevant to climate policy; and assessing the choice processes of decision making in the private and public sectors.

It is also crucial for the IPCC to strategically time the release of its products in order to ensure their utmost pertinence. While the Fifth Assessment Report provided key input to the deliberations at the Twenty-first session of the Conference of the Parties (COP21), it would be useful for the AR6 to expand its scope and notions in order to facilitate the implementation of the SDGs as well as the milestones achieved at COP21. Indeed, we now have global goals with the Paris Agreement seeking to strengthen the global response to the threat of climate change, limiting the global average temperature to well below 2C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5C. Countries' Nationally Determined Contributions will be revised on a 5-year basis through a global stocktaking mechanism established under the UNFCCC, which will start in 2023.

[1] UNGA A/RES/43/53, 1988

The AR6 cycle, which will consist of a methodological report, three special reports, three Working Group (WG) assessments and the synthesis report (SYR), will strive to be aligned with the first cycle of the global stocktake, in order to feed effectively into the process. The IPCC's work will be meaningful to the Convention if it can provide comprehensive and robust science-based information on where the global community may be in meeting the challenge of climate change, and comparing the latter with where the global community could be given expressed willingness to act. This vision paper outlines the Chair's vision on how the AR6 can best achieve this, taking into consideration views expressed by the governments through the pre-scoping questionnaire. The WG contributions are in Part B in this document and specific cross-cutting issues across WG which will require specific scoping considerations are highlighted in Part C.

The AR6 feeding into the work of the UNFCCC

The IPCC has already acknowledged that it will plan for the AR6 to be finished by 2022 and further assessment cycles to be synchronized with the cycles of the global stocktake starting in 2023. The Subsidiary Body for Scientific and Technological Advice (SBSTA) and the IPCC organized a joint event in May 2016 in order to better exchange views, based on the AR5, on what may be relevant for the global stocktake and what may be considered in the AR6. In order to be helpful to the process, the IPCC must therefore align the timing of the release and the content of the AR6 with the requirements of the global stocktake. In terms of timing, the IPCC plans to approve the outlines of the 3 WG contributions to the AR6 in September 2017; WGI contribution to the AR6 will be approved in April 2021; WGIII contribution to the AR6 will be approved in July 2021; WGII contribution to the AR6 will be approved in October 2021; and the AR6 SYR will be adopted in April 2022; hence, all elements of the AR6 will be available for consideration by the global stocktake in 2023, and the IPCC will be in a position to provide the policy relevant scientific input to the global stocktake under Article 14 of the Paris Agreement.

Noting that there is still little clarity concerning what the global stocktake may consist of, the IPCC must be aware of what we already know concerning the stocktaking exercise, what it consists of and its purpose, in order to be able to produce relevant information. Article 14 of the Paris Agreement defines it as such: "The Conference of the Parties serving as the meeting of the Parties to this Agreement shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the “global stocktake”). It shall do so in a comprehensive and facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science". The core purpose of the stocktake is the aggregation and assessment of the Parties' efforts, for the continuous increase in ambition and science-based information provided by the AR6 as input to meet this purpose would be most useful. "Collective" being the first defining feature of the global stocktake points to the fact that a global effort is required for the stocktake to succeed, and this implies that the information relevant to the process would enable a broad ownership and inclusiveness of the exercise by all stakeholders involved, including policy-makers and civil society. Article 14 then defines it as "comprehensive", meaning that the scientific input required may include the assessment of climate change and human influence on global climate, the assessment of the progress of mitigation, adaptation, means of implementation, indicators of near term emission pathways and comparison with long-term goals, and in terms of investment patterns in infrastructure. Globally-agreed metrics for adaptation would also contribute to a comprehensive assessment of progress in global responses, and there is a role for the scientific community to play in the development of such metrics, with the IPCC providing a comprehensive assessment of the available literature. Finally, the global stocktake is meant to be "facilitative" towards the acceleration of progress. In this regard, the scientific community may consider delivering information that will illuminate pathways to further ambition. Such information comprises the assessment of decision-making frameworks and processes, of incentives for investment in low-carbon and low-emissions development, of private sector decision-making and of consumer behavior, recognizing the fact that scientific and technical information can guide better decisions but alone are insufficient to achieve them.

It is also important to take note of what the global stocktake will not aim to do; for instance, the APA co-chairs have stated that the exercise will not attempt to assess the adequacy of individual NDCs but rather, the degree to which in aggregate, they match up to overall aims of the Paris Agreement. In this regard, it should be noted that it would not be appropriate for the IPCC to assess the NDCs either, but rather to provide methodological support for a process which will be inevitably UNFCCC-led. More specifically, the kind of science-based information that would contribute to increasing the ownership and inclusiveness of the global stocktake, as well as its comprehensiveness and facilitative nature would be information related to the newly adopted goals of well below 2.0°C striving for 1.5°C and progress towards them; information contributing to the assessment of the aggregation of NDCs given the acknowledged gap between these and the global goals; information on the pace, frequency and intensity of near- and long term climate change; rigorous assessment of key vulnerabilities and major risks across sectors, including risks of abrupt and/or irreversible changes and early detection; information on short-lived climate pollutants in the context of the Paris Agreement temperature goals; information on impacts in key sectors associated with different GHG emissions pathways, and economic evaluation associated with uncertainty estimates; information on peaking of global emissions and implications regarding the global goals; solution-oriented information for bridging the emissions gap; assessment of adaptation and mitigation policy effectiveness and technology needs; options for scaling up ambition such as low-emissions scenario policy options, and negative emissions options to meet the global goals; comprehensive assessment of geoengineering options; information on co-benefits of climate measures; information and methodologies related to the global adaptation goal and how to measure the collective progress (metrics); how to assess the effectiveness of finance measures; and emphasis on regional aspects.

In order to stay in tune with the international agenda, the AR6 will also have to provide science-based information relevant to Article 2 of the Convention, in order to help the Parties "to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". The AR6 should also respond to Articles 4.8 and 4.9 which request "to meet the specific needs and concerns of developing country parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures." The needs of these specific stakeholders should be considered in the elaboration of this report.

The AR6 feeding into the post-2015 agenda

The Paris Agreement and its goals are not the only items of the global development agenda. There are other global goals and frameworks which have direct and indirect implications for both climate change impacts and emissions reduction pathways, and hence the AR6 may also consider the kind of information relevant to their implementation. These include the Sendai Framework for Disaster Risk Reduction, the 2030 Agenda for Sustainable Development (the SDGs) including a climate action goal, and the New Urban Agenda which was adopted at the UN Habitat III Summit in October 2016. The AR5 established that climate-resilient pathways and sustainable development can be mutually supporting, and that effective implementation depends on cross-sectoral cooperative action at all scales, through integrated responses that link adaptation, mitigation and other societal objectives. It is therefore crucial that the AR6 does not focus solely on meeting the information needs for the implementation of the Paris Agreement, but adopts a comprehensive approach to meet the information needs relevant to implementing the broader global development agenda, such as synergies between adaptation and mitigation in the context of sustainable development, associated costs, co-benefits and risks, and climate action solution in the context of pursuing the SDGs.

The AR6 must fit coherently into the IPCC's line of work

While the AR6 main report will undoubtedly be the predominant and most comprehensive product that the IPCC will produce during its sixth assessment cycle, it is not the only one and the scoping of the AR6 should be mindful of the other reports that will be prepared by the IPCC during the assessment cycle, in order to avoid overlaps between products. Other relevant assessments such as by IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem services), IUCN (International Union for Conservation of Nature), UNEP and UN will also need to be considered. A key outcome of the AR6 scoping meeting will be to produce an outline that comprehensively covers all crucial topics, bearing in mind those that are specifically being covered by the other Special/Methodology reports; and to work out how to integrate these topics in the AR6 without being redundant yet without leaving them out altogether. The other reports scheduled during the AR6 cycle are:

- a Special Report on global warming of 1.5°C, scheduled for 2018;

- a Special Report on climate change and oceans and the cryosphere, scheduled for 2019;

- a Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, where the scoping process may consider opportunities for both adaptation and mitigation, scheduled for 2019;

- a Methodology Report to update and supplement the 2006 IPCC Guidelines for National Greenhouse Gas Inventories , scheduled for 2019.

The 43rd Session of the IPCC (P-43) decided that all of the topics contained in the 31 Special Report Proposals (IPCCXLIII/Doc.7) are important and should be considered during the scoping exercise of the AR6 across the three Working Groups. P-43 also decided to recommend within the AR6 scoping process, a stronger integration of the assessment on the impacts of climate change on cities and their unique adaptation and mitigation opportunities, and make more robust the consideration of cities in the treatment of regional issues and in chapters that are focused on human settlements, urban areas and the like, including through enhanced engagement of urban practitioners.

The scoping of the AR6 WG and SYR reports should therefore consider the flow of information and the complementarity of the various elements of the AR6, with special attention to the Special Reports.

Cross-cutting issues across WG reports:

The cross-cutting issues in the AR6 must be carefully handled with the full involvement of all Working Groups to ensure consistent treatment. In the AR5, 8 cross-cutting issues were identified during the scoping meeting: uncertainties and risks, costing and economic evaluation, regional aspects, water and earth system, carbon cycle including ocean acidification, ice sheet and sea level rise, mitigation, adaptation and sustainable development, and Article 2 of the Convention. A concept note on cross-cutting issues was then developed by the IPCC Vice-Chairs and the WG Co-Chairs, providing for each issue a background and scope, a suggested Working Group involvement, and a suggested approach for the treatment of the issue. In the AR5 scoping, the IPCC Vice Chairs and the WG Co-Chairs, with the assistance of the Technical Support Units (TSUs) and IPCC Secretariat, provided a document as input to the scoping meeting, analyzing the treatment of cross-cutting issues in the TAR and the AR4, suggesting improved methods for a strengthened treatment of cross-cutting issues in the AR5, and suggesting new such issues relevant to the AR5 cycle. The IPCC Vice-Chairs and the WG Co-Chairs were responsible for the smooth handling of the cross-cutting issues.

The cross-cutting issues identified for the AR6 may be the same as those in the AR5, or evolve into new ones depending upon outcome of the scoping meeting. Part C in this document identifies preliminary cross-cutting issues for the AR6 from the WG Co-Chairs. Specific time will be allocated

during the scoping meeting to explore specifically how these and other cross-cutting issues may be best addressed in the AR6.

AR5 key conclusions and gaps

When scoping for the AR6, it is useful to recall the AR5's key conclusions and identify which are the knowledge gaps at the time of the assessment, and to consider the emerging science since its publication. Major conclusions of the AR5 were:

- Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.

- Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.

- Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term, and contribute to climate-resilient pathways for sustainable development.

- Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales, and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

Some emerging themes and outstanding issues, outlined as “key uncertainties” by AR5 WGI and as “research and data gaps” by AR5 WGII and WGIII can be identified in the AR5, beyond these major conclusions. As there may be few completely new areas to be explored, efforts should also focus on improving spatial resolution within regions and reducing uncertainties when filling knowledge and data gaps. Part B of this document elaborates on these gaps.

In this respect, it is proposed that no revision to IPCC’s guidance on the consistent treatment of uncertainties is made for the AR6 cycle. The Chair and co-chairs believe that this provides solid guidance to authors and, with clarification and explanation at the Working Group level, will effectively inform the authors’ work.

Integrating the risk and solution-based frameworks

In the AR5, the climate change impacts and responses were essentially viewed through a risk-based framing approach, developed mostly by WGII. This approached conceptualized the risks arising from the overlapping of climate hazards, exposure and vulnerability, leading to impacts that provide feedback to socioeconomic processes and the climate system. The AR5 assessed the potential for reducing the risks through both adaptation and mitigation. The concept of risk in the AR5 was derived from a rich set of literatures on risk, risk perception and risk management, and these are entirely compatible with a solution-based framework and indeed derive from similar motivations. The integration of the risk framework with the solutions-focused, problem-solving frameworks should be the overarching framing of the AR6. This would require approaching climate risks in the context of the full spectrum of risk profile that societies face. The IPCC does have, as part of its mandate, the "formulation of realistic response strategies".

Gearing up ambition under the Paris Agreement and its implementation requires solution-oriented information. Bearing in mind the outline of SR1.5 and avoiding overlaps, it would be relevant for the AR6 to explore questions related to global-scale opportunities to avoid carbon lock-ins and leading to transformational change, including for the sectors of energy systems and renewable energy, water resources, agriculture, health, industry, food production, security and consumption, cities and urban planning, transport, AFOLU, coastal management, human security, disaster risk reduction and management, capacity building and ecosystems; options for decarbonization pathways, including solutions for business which can contribute to an increase in ambition in country NDCs; options for the mobilization of various stakeholders to achieve low emissions pathways and SDGs; opportunities that can help implement the international development agenda while simultaneously providing climate benefits; and ways in which countries can achieve their development and climate goals. It should also address the potential for reducing the specific risks of both adaptation and mitigation. Barriers to these pathways need to be clearly identified and assessed.

Multi - and inter-disciplinary integration

It is essential that the experts involved in the scoping of the AR6 and eventually its writing, consider and meet the challenge of integrating knowledge from different social and natural scientific disciplines, in order to give a coherent and comprehensive picture of climate change and its impacts, and of the economic and social impacts of different emissions pathways, and associated transformational challenges and opportunities. Different levels of climate change and their impacts place before policy-makers and society the challenges of implementing adaptation and mitigations measures corresponding to these levels of climate change; and some scenarios require more transformational changes than others, presenting a mix of opportunities, challenges and trade-offs.

Producing an AR6 which documents different levels of transformational societal changes requires different types of knowledge ranging from physical science, to ecological and economic sciences, to humanities and social sciences, as well as knowledge drawn from the practitioner community. This will require the experts involved in the scoping and writing exercises of the AR6 to undertake concerted multi- and inter-disciplinary conversations, across-WGs but also intra-WGs, and to be mindful of the needs of the practitioner community, especially as the AR6 is meant to adopt a risk and solution-oriented framing. It will be crucial to engage with key user communities and work with academia, urban practitioners, policymakers at national and sub-national levels, private sectors and relevant scientific bodies and agencies early and throughout the AR6 cycle, in order to craft a narrative that works at different levels of complexity, and to ensure integrative discussions of major scientific issues associated with integrative risk management and sustainable solutions, including across the areas of planetary and regional climate risks (WGI), societal and ecological risks (WGII) and abatement of risks through adaptation and mitigation (WGII and III). Indeed, the AR6 should be relevant for stakeholder challenges as broad as disaster risk management, economic and sustainable development policies, adaptation planning, mitigation policies, impacts of response measures and increasing resilience.

Treatment of regional aspects

Finally, modalities for the appropriate treatment of regional issues in the AR6 remain one of the most important tasks for experts to consider at the scoping of the AR6, as IPCC member governments have themselves explicitly demanded increased policy-relevant regional downscaled information, with the aim of filling the noted gap in scientific information and projections at the national, regional and local levels. These, particularly in light of the increase in regional and local scale climate data and studies, are now available.

In AR5, regional assessments comprised 11 chapters in WGI and II (690 pages in total), and were accompanied by the WGI Atlas of Global and Regional Climate Projections. As noted by the Co-Chairs, it will be crucial to the AR6's success to enhance regional perspectives in AR6 in line with Plenary Decision IPCC/XLI-4 on the Future Work of the IPCC. This will help respond to the request, under paragraph 45 of Decision CP.21 of the COP21 Paris meeting, for Parties to strengthen

regional cooperation on adaptation. While IPCC assessments are based on peer-reviewed literature, Parties have also expressed that the IPCC may be able to enhance the regional perspective in the AR6 through the use of increasing information available from the regional, sub-regional and national levels, consistent with the IPCC agreed guidance on the use of peer-reviewed and grey literature in reports, building on the full range of available knowledge, including indigenous and practice-based knowledge relevant for the assessment to support sustainable low-carbon pathways, adaptation and biodiversity.

Communications

It is crucial to remember, when scoping for the AR6, that it will be communicated to non-specialists. In this regard, the structure of the report, as logical and focused as possible, as well as a consistent use of terminology across the AR6, will go a long way in improving its readability and comprehensibility. This is why getting the framing of the report right, through the double risk and solution-based approach, is essential: a consistent framing throughout the report will enable a coherent assessment across WGs and chapters. It may also be useful, while drawing up the outline of the AR6, to aim for clear headline messages which will make sense in substance and in order when read in sequence, as well as to remember that quality should always outdo quantity and that a shortening of the AR6 would probably improve its policy relevance.

To enhance communication, it is proposed that each Working Group adopts the practice pioneered by Working Group I in AR5 of including headline statements in their SPMs. This practice would also apply to each of the Special Reports under development during the AR6 cycle. Similarly, it is proposed that all Working Groups take a similar approach to FAQS, with these being embedded in chapter text so that the context is clear,

The following Part B sets out the vision of each of the Working Groups regarding their contributions to the AR6 reports. Part C identifies cross-cutting issues.

B. Contributions of the three Working Groups

Contribution of Working Group I

List of acronyms

AMOC	Atlantic meridional overturning circulation
AR5	Fifth Assessment Report of the IPCC
AR6	Sixth Assessment Report of the IPCC
BECCS	Bioenergy with carbon capture and storage
CCS	Carbon capture and storage
CDR	Carbon dioxide removal
CMIP5	Coupled Model Intercomparison Project, phase 5
CMIP6	Coupled Model Intercomparison Project, Phase 6
CORDEX	Coordinated Regional Climate downscaling Experiment
DCPP	Decadal Climate Prediction Project
ENSO	El Niño – Southern Oscillation
GHG	Greenhouse gases
ITCZ	Intertropical convergence zone
RCP	Radiative concentration pathways; four greenhouse gas atmospheric concentration pathways used in IPCC AR5.
WCRP	World Climate Research Programme
SREX	IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SR1.5	IPCC Special Report on Global Warming of 1.5°C
SROCC	IPCC Special Report on Climate Change and the Ocean and the Cryosphere
SR2	IPCC Special Report on Climate Change and Land
SRM	Solar radiation management
SSP	New scenario framework for climate change research, combining pathways of future radiative forcing and socio-economic development, with five narratives, designed to represent different mitigation and adaptation challenges.
SST	Sea surface temperature
TFI	IPCC Task Force on Inventories
WWRP	World Weather Research Programme
WG	Working Group of the IPCC (WGI, WGII and WGIII)

A. Introduction: from AR5 to AR6

The IPCC Working Group I (WGI) is dedicated to the assessment of the physical science basis of climate change, through a **rigorous, transparent, comprehensive and robust** assessment of the state of knowledge. The Sixth Assessment Report (AR6) will be an opportunity to highlight the contribution of new knowledge from the "physical science" basis to understand past, present and future climate change (see section B) and to provide key information for risk management, adaptation and mitigation options, which will be the topics of the WGII and WGIII reports. The findings and assessment in the AR6 WGI report will also feed into of the AR6 Synthesis Report.

The AR6 WGI report, scheduled for publication in 2021, will build on **fundamental physical science developments** conveying new knowledge from observations, theory and models, with a focus on process-based understanding.

Several dimensions have to be considered in designing the structure and indicative content of the AR6 WGI report: changing perspectives since the AR5, key uncertainties and gaps evidenced in the AR5, new emerging knowledge, coordination of the assessments performed in the three IPCC AR6 Special Reports scheduled for 2018 and 2019 and the main assessment report, and coordination with WGII and WGIII reports. The assessment of the relationships between future socio-economic scenarios, greenhouse gas emissions pathways, radiative forcing and global climate projections requires close integration between the WGI and WGIII reports. It is particularly important to design a report structure to allow a detailed and comprehensive assessment of regional and sectorally relevant climate information, building on ongoing research developments to bridge with the WGII report, addressing the expectations from stakeholders.

Thinking upfront of the distillation of the report towards **information relevant for end-users** (policy-makers, business sectors, etc) was a recommendation of the IPCC Expert Meeting on Communication[2]. Challenges for the AR6 WGI report also include assessing and explaining the state of knowledge relevant for the global stocktake of the Paris Agreement and long-term climate goals. The AR5 WGI Summary for Policymakers developed "headline statements" [3] **to communicate** robust and compelling results in a way that is easily accessible. The AR6 report is expected to reinforce efforts to best communicate the assessment results[1] (Chair's vision: Communications), also building on knowledge on readability of figures[4]. The WGI report is expected to use boxes and FAQs to facilitate communication to a range of audiences, and to improve the readability of executive summaries of each chapter.

This document introduces scoping considerations (section B), encompasses an analysis of key findings and gaps from the AR5 WGI report (section C), and identifies a range of emerging topics since the AR5 (section D). These examples of new knowledge are identified to stimulate the scoping discussions on the structure of the WGI report, revisiting the report structure successfully implemented in the AR4 and AR5 reports, and to define the focus of chapters, number of chapters, and indicative content and length. Examples of cross-cutting issues across Special Reports that are relevant for WGI are provided in section E, and cross-cutting issues that need to be carefully considered across the WGs during the AR6 scoping are highlighted in Part C of the Vision Document (p.42).

---

[2] *http://www.ipcc.ch/pdf/supporting-material/EMR_COM_full_report.pdf*

[3] *http://www.climatechange2013.org/headline-statements/*

[4] *McMahon, R., M. Stauffacher and R. Knutti (2016). "The scientific veneer of IPCC visuals." Climatic Change **138**(3): 369-381 ; Harold, J., I. Lorenzoni, T. F. Shipley and K. R. Coventry (2016). "Cognitive and psychological science insights to improve climate change data visualization." Nature Clim. Change 6(12): 1080-1089.*

B. AR6 WGI Scoping Considerations

The major themes identified in the call for nominations for participants in the scoping meeting and relevant for the AR6, WGI report are:

- ✓ The climate system (atmosphere, land surface, ocean, cryosphere): past and present observations, processes, and interactions
- ✓ Natural and anthropogenic drivers of large-scale climate change (land use, well-mixed greenhouse gases, short-lived forcers including aerosols), carbon and other biogeochemical cycles
- ✓ Developments in climate modelling, model evaluation, predictability and predictions, scenarios and projections, detection and attribution, on global and regional scales
- ✓ Earth system feedbacks and dynamical responses, including abrupt change
- ✓ Climate variability, climate phenomena and teleconnections, extremes and implications for regional climate

Three themes were cross-cutting areas of expertise, also common with WGII and WGIII:

- ✓ Climate engineering, greenhouse gas removal, and associated feedbacks and impacts
- ✓ Regional and sectorial climate information
- ✓ Epistemology and different forms of climate related knowledge and data, including indigenous and practice-based knowledge

Recommendations from the co-chairs for the AR6, WGI report include the following:

- ✓ The report structure should bring forward robust and compelling results in a way that is easily accessible to stakeholders.
- ✓ The WGI report should have a limited number of chapters (less than 15) in terms of production feasibility;
- ✓ The scoping should carefully consider the outlines of the three Special Reports under preparation, and the timeline of new research developments. It is expected that new climate projections arising from CORDEX and CMIP6 be available from the peer-review literature for assessment in the AR6.
- ✓ The scoping should consider carefully the strengths and weaknesses of the AR4 and AR5 Working Group I reports which had a similar design and structure, with chapters on observations, process understanding (paleoclimate, biogeochemical cycles, aerosol and clouds, atmospheric chemistry, radiative forcing), and then model evaluation, and their application for detection attribution and projections, expanding towards regional information. The evaluation of structure of AR4 and AR5 will form input to considerations of design and structure of AR6.
- ✓ The scoping should anticipate the need for a more comprehensive assessment of extreme events. The AR5 WGI report was able to refer extensively to the then recently-completed Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX).
- ✓ The scoping should facilitate a comprehensive assessment of multiple sources of regional climate information, including downscaling methodologies. The AR5 WGI report did not assess information from regional downscaling, due to the lack of available multi-model comparisons from the peer-review literature at that time.
- ✓ The report structure should reflect science developments, including improved process based understanding (e.g. anthropogenic drivers, storage and flows of energy in the climate system, climate feedbacks, carbon cycle, water cycle etc.).
- ✓ The report structure should facilitate the integration of observations and simulations, and, where possible, strengthen the use of model evaluation in the assessment of confidence in projections of future climate change.

- ✓ The report structure should facilitate integration with WGII (e.g. regional climate information, sectoral relevance, ecosystems) and WGIII (e.g. drivers, scenarios and pathways, AFOLU).

During the scoping meeting, it may be relevant to revisit the AR5 **guidance notes**, and carefully discuss whether it is necessary to reconsider them.

The AR5 introduced a coherent approach of assigning explicit and calibrated **uncertainty language**[5] to key findings of the report, either through specifying a qualitative level of confidence (e.g. "medium" or "low" confidence if confidence was limited) or, if the evidence permits, a quantified likelihood that a certain finding is true. This new approach for the uncertainty language introduced a discontinuity preventing easy comparison of conclusions with those from the AR4. Unless there is a compelling reason to alter the AR5 approach, co-chairs recommend that no new discontinuity is introduced in the AR6 with respect to the calibrated uncertainty language.

The IPCC Good Practice Guidance Paper on **Detection and Attribution related to Anthropogenic Climate Change**[6] may have to be revisited to expand on methodologies for the attribution of extreme events, potentially including single events. Similarly, the Good Practice Guidance Paper on **Assessing and Combining Multi Model Climate Projections**[7] may be expanded, for instance to account for the variety of downscaling methods, with a focus on regional information. The scoping meeting is an opportunity to provide recommendation for Workshop or Expert Meetings on such specific topics[8].

C. Key uncertainties and gaps identified in AR5 WGI and SREX

The IPCC AR5 comprehensively assessed observed changes in the climate system and understanding of climatic drivers, based on available observational datasets, reanalyses and information from paleoclimate archives**.** Thanks to newly available ocean datasets, the AR5 performed a comprehensive assessment of changes in energy in the climate system (including ocean heat content), and an assessment of each component of the observed sea level rise.

Key uncertainties are associated with limits in observing capabilities, data incompleteness, inconsistencies across datasets, and/or large inter-annual to decadal variability. This was highlighted in the AR5 for the vertical structure of atmospheric temperature change, as well as for multi-decadal to centennial changes in large-scale atmospheric circulation, global land precipitation, global scale cloudiness, global scale drought, and tropical cyclone characteristics.

Similarly, large uncertainties were reported for observed variability and long term trends in subsurface ocean temperature, carbon and heat content, especially below 2000 m, as well as changing strength of ocean circulation features, and characteristics of Antarctic sea ice (e.g. thickness), due to limited observations.

The AR5 also identified key gaps in observations of ocean / ice sheet interactions, and observations of ice sheet mass loss at this interface.

It stressed large uncertainties in aerosol-cloud interactions, identified to be the largest uncertainty associated with anthropogenic forcing, despite a better understanding of some of the relevant atmospheric processes and the availability of global satellite monitoring. While the AR5 concluded that for positive feedbacks associated with clouds and with the carbon cycle are generally positive, it also stressed the large uncertainty associated with the strength of these feedbacks. There was no comprehensive assessment of dust feedbacks in the AR5.

---

[5] *https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf*
[6] *http://wg1.ipcc.ch/guidancepaper/IPCC_D&A_GoodPracticeGuidancePaper.pdf*
[7] *http://wg1.ipcc.ch/guidancepaper/IPCC_EM_MME_GoodPracticeGuidancePaper.pdf*
[8] For the list of past IPCC Workshops and Expert Meetings, including those associated with Good Practice Guidance Papers, see: *http://www.ipcc.ch/publications_and_data/publications_and_data_supporting_material.shtml*

The conclusions of the assessment of human influence on the climate system was strengthened from AR4 to AR5, and several key uncertainties were identified

The AR5 concluded that it is virtually certain that internal variability alone cannot account for the observed global warming since 1951, and that it is extremely likely that human influence has been the dominant cause. The AR5 stressed the importance of climate model developments since the AR4, including e.g. the representation of key aspects of biogeochemical cycles, and model improvement. It expanded the attribution to human influence towards regional temperature change, Arctic sea ice retreat, and sea level rise. Several key limitations were identified for detection and attribution of human influence, such as observational uncertainties for variables other than temperature, uncertainties in aerosol forcing, modeling uncertainties and limits in process understanding for several aspects of the climate system.

Challenges for attribution were thus identified for changes in the water cycle (including clouds), with combined uncertainties associated with observations and the ability of models to capture trends and internal variability; for regional changes, due to the importance of internal variability and challenges associated with model resolution and incorporation of relevant processes (e.g. land surface / atmosphere feedbacks); for the frequency and intensity of some extreme events, for which attribution is limited by the ability of models to simulate mean changes; and for changes in some aspects of the climate system (drought, tropical cyclone activity, Antarctic sea ice, temperature and mass balance), due to uncertainties in observations, modeling uncertainties and divergent results. While the AR5, WGI report dedicated its last chapter to climate phenomena and their relevance for future regional changes, there was no comprehensive assessment of their role in observed regional climatic changes.

The AR5 had to rely on expert judgment for its assessment of the observed recent warming hiatus, defined as the lower warming trend in 1998–2012 as compared to the 1951–2012 trend, attributed in roughly equal measure to internal variability and a reduced trend in external forcing (medium confidence). At the time of the AR5, there was low confidence on estimates of forcing trends (due to uncertainty on anthropogenic aerosol and volcanic aerosol forcing), and on the exact processes of internal variability at play, due to the lack of peer-review publications assessing related observations and relevant initialized climate simulations. Since the AR5, the ‘hiatus’ or ‘warming slowdown’ has been extensively discussed in the scientific literature.

The CMIP5 (the Coupled Model Intercomparison Project Phase 5) model outputs provided an unprecedented level of information for analysis of historical simulations, paleoclimate simulations and **projections**. The AR5 showed that projected climate change based on RCPs (the Representative Concentration Pathways, a new set of scenarios for AR5) is similar to AR4 in both patterns and magnitude, after accounting for scenario differences. The RCP scenarios consider changes in land use through vegetation cover, but do not account for local anthropogenic effects associated with urbanization and irrigation or feedbacks associated with land degradation. The AR5, WGI focused on vegetation cover and carbon feedbacks with respect to interactions between land surface, land use changes and climate change.

Compared to earlier IPCC assessment reports, the AR5 included a novel chapter on **near term** climate projections and predictability. The assessment concluded that there was limited confidence in predictability for annual to decadal average temperature, at global and regional scale, low predictability for precipitation, medium confidence for near-term projections of changes in Northern Hemisphere storm track, and stressed limitations associated with uncertainty in future natural forcings. For the near term, the AR5 stressed that the response of air quality to climate-driven changes is more uncertain than the response of **air quality** to emission-driven changes. While warmer conditions in polluted regions are understood to increase peak levels of ozone and PM2.5, the assessment stressed low confidence in projecting meteorological blocking, and implications for associated regional extreme pollution episodes.

The AR5 WGI did not include a comprehensive assessment of what would be the climate response to a potential future major **volcanic eruption (in the context of climate projections)**, and WGII did not assess what would be the potential impacts and response options.

The AR5 showed modest improvement in the simulation of **clouds** in CMIP5 models, and stressed that simulating trends and variability in the **water cycle** remains challenging. The AR5 assessed the plausible range of climate sensitivity by combining information from statistical analyses of paleoclimate and historical changes, as well as the range of CMIP5 model results. It did not assess how process-based knowledge on individual feedback processes (including clouds) may affect the estimate of climate sensitivity, or the reasons for inconsistent findings on climate sensitivity based on historical trends and future climate projections.

The AR5 projections reported in WGI only relied on global climate models. In the WGII regional chapters, **regional projections** from CORDEX were assessed for Europe only. The WGI report did not assess projections specifically for oceanic zones or systems (e.g. coastal or equatorial upwelling), nor for combined changes in ocean warming, acidification and loss of oxygen. There is thus potential for improved coordination between WGI and WGII for regional aspects as well as for terrestrial and marine ecosystem aspects.

For **sea level** projections, the AR5 noted the **lack of knowledge** on dynamical Antarctic ice sheet response on time scales of centuries, and did not assess what could be a physically plausible upper bound for sea level risk by 2100 and beyond.

Based on model evaluation, understanding of physical processes and range across projections, the AR5 stressed **low confidence for projected trends** in tropical cyclone frequency and intensity, for future changes in regional monsoons, for regional aspects of projected changes in soil moisture and runoff and for many aspects of climate phenomena that influence regional climate change, such as the amplitude and patterns of modes of climate variability, for example projected changes in the El Niño-Southern Oscillation (ENSO) and associated teleconnections.

The AR5 introduced the concept of a **carbon budget** related to long-term climate stabilization goals, and showed that limiting climate change would require substantial and sustained reductions in emissions of GHG emissions. The near linear relationship simulated by all models between global temperature and cumulative carbon results from the interplay of several compensating carbon cycle and climate feedback processes operating on different time scales, which depend on the modeled climate sensitivity and carbon cycle feedbacks. The AR5 therefore stressed that allowed emissions for a given temperature target are uncertain, with many studies ignoring non-CO_2 drivers. The AR5 also provided an assessment and update of emissions metrics used for multi-gas mitigation policies and assessments (WGIII).

The AR5 stressed the lack of consensus and confidence on the likelihood of **abrupt and non-linear changes,** despite the theoretical potential of such behavior for several components of the climate system, and insights from past climate variations. The AR5 also stressed the large uncertainties associated with several aspects of carbon cycle feedbacks, such as greenhouse gas emissions from gas hydrates from seafloor, wetlands, soils, and thawing permafrost.

Finally, the AR5 assessed knowledge relevant for **carbon dioxide removal (CDR) and solar radiation management**. Biogeochemical and technological limitations for CDR were stressed. However, it was difficult to quantify how much CO_2 emissions could be offset by CDR on a human time scale, and potential carbon cycle rebound effects were identified. For solar radiation management methods, the AR5, WGI report considered research to be in its infancy and highlighted uncertainties associated with the understanding of aerosol and cloud interactions as well as side effects, risks and shortcomings from SRM.

The **SREX** assessment reported heterogeneous results for different regions and for different extremes. The AR5 investigated changes in extreme events, using indices of temperature and precipitation extremes. It stressed the challenges associated with statistical significance of observed trends and geographically heterogeneous results, strongly affected by internal variability. The report did not assess knowledge on compound extremes events (e.g. simultaneous heat waves and drought, or intense winds and heavy rainfall) which have specific relevance for risk management. The SREX stressed that confidence for changes of tropical cyclone, droughts, and small-scale extremes remained low. It did not assess extreme events from an ocean perspective (e.g. marine heat wave).

D. New issues and anticipated developments

Climate change science has advanced since the AR5, as a result of new observations and analyses of datasets, including reanalyses, process-based understanding and model development. This section provides a brief description of some important but non-exhaustive emerging knowledge.

Global energy budget: a crucial dimension to understanding climate variability and change is the ability to observe and understand each component of the Earth's energy budget, building on comprehensive monitoring of the climate system and radiative fluxes from in situ and space data embedded in the Global Climate Observation System (GCOS). Progress in the ocean observing system and estimations of surface fluxes are important for improved understanding of the Earth's energy imbalance. Assessing the state of knowledge, including reanalyses and model skills, is expected to be a key component of the AR6. It may provide the opportunity to link the assessments of radiative forcing and energy budgets.

Land surface – atmosphere processes: new knowledge arises from in situ monitoring, field experiments, and developments of Land Surface Models (LSM). The current generation of LSMs explicitly model plant physiological and biogeochemical processes, and may simulate leaf phenology, the carbon cycle, community composition, and vegetation dynamics. Ongoing developments including linkages among biogeochemical cycles (carbon, nitrogen and phosphorus); soil biological processes; reactive gases and atmospheric chemistry (including dust, biogenic volatile organic compounds, atmospheric oxidant capacity, nitrogen emissions, methane, ozone, and secondary organic aerosols) that also are important for air quality; representation of wetlands, river flow, soils, groundwater, and cryospheric processes (e.g. thawing permafrost); managed ecosystems, including cropland, forestry and pastures; and urban areas. While the LSMs are designed for coupling with atmospheric models and specifically simulate terrestrial feedbacks with the atmosphere, an emerging frontier is to apply LSMs for climate change impacts, adaptation, and mitigation research and for studying regional climate feedbacks, in relationship with SSP scenarios.

Aerosol and cloud processes: Long-term monitoring efforts are dedicated to observations of atmospheric aerosol particles (incl. dust) and cloud properties, and their connections with atmospheric chemistry and physics and atmospheric circulation, using in situ stations as well as remote sensing and satellite data and regional cloud resolving models. New understanding of atmospheric chemistry and physics and aerosol processes is expected to strengthen the knowledge associated with air quality response to changing emissions as well as changing climate conditions. New observations also lead to new parameterizations of convection and cloud processes in climate models, and to the combined use of observations and simulations to link cloud processes with global climate metrics (e.g. climate sensitivity). It is important that the scoping of the AR6 is designed to facilitate the flow of information from new observations, process based understanding, model evaluation and projections, especially in relationship to aerosols and clouds. Diagnoses of forcings and feedbacks in observations and climate simulations are expected to contribute to such analysis.

Radiative forcing: Since the AR5, new studies have been dedicated to the spectroscopic basis of GHG radiative forcing calculations, including revised estimates for methane radiative forcing.

Uncertainties related to the effect of black carbon are large, and developments are expected, for instance for effects of black carbon on ice and mixed phase clouds. Revised emission inventories for short-lived drivers have been published since the AR5. Further developments on the concept of effective radiative forcing and quantification of rapid adjustments are also emerging and are relevant for the AR6.

Global climate model developments and evaluation: The ongoing sixth phase of the Coupled Model Intercomparison Project (CMIP6[9]) consists of three major elements: (1) a suite of common Evaluation and Characterization experiments and CMIP historical simulations (from 1850 to near present) that will maintain continuity and help document model evaluation across different phases of CMIP; (2) an ensemble of CMIP Endorsed Model Intercomparison Projects (MIPs) that will be specific to CMIP phases and help to address a range of research questions and fill some of scientific gaps of the previous CMIP phases; and (3) common standards, coordination, infrastructure, and documentation that will facilitate the distribution of model outputs and the characterization of the model ensemble. CMIP6 will make use of an updated set of forcing scenarios (emissions or concentrations of greenhouse gases and aerosols, land use, solar and volcanic forcing) that have been developed in conjunction with a set of Shared Socio-economic Pathways (SSP) scenarios.

The knowledge emerging from the new Model Intercomparison Projects and other studies will contribute to many aspects of model evaluation, process understanding, detection and attribution, and projections, including cloud processes, precipitation, radiative forcing, predictability. An important gap identified in previous CMIP phases, was the lack of careful quantification of the radiative forcings from the different specified forcing factors (e.g. GHGs, sulphate aerosols, land use) in each model. This has impaired attempts to identify reasons for differences in model responses. CMIP6 is designed to to track changes in performance and response characteristics over the new generations of models and understand the spread of model responses.

Long-term projections: new CMIP6 projections will use the Shared Socio-economic Pathway (SSP) scenarios. New information may be available on climate response to ambitious stabilization scenarios, to scenarios with an overshoot and decrease in radiative forcing, on Earth system feedbacks (biogeochemical cycles; ice sheets), encompassing multi-centennial responses. The AR6 is expected to consider comparison with CMIP5/RCP results, and ensure coherency with the Special Report on Global Warming of 1.5°C (SR1.5) by reporting projections along timelines of scenarios, but also as a function of global warming amplitude.

Climate Prediction: research is on-going on the potential for skillful initialized forecasts across timescales (sub-seasonal, seasonal to decadal), through predictability and sensitivity studies, retrospective hindcasts and forecasts using climate models and statistical approaches. Efforts are coordinated, for example within the WCRP-WWRP Sub-seasonal to Seasonal Project (S2S) and WCRP CMIP6 Decadal Climate Prediction Project (DCPP). This area is relevant for strengthening model evaluation, the assessment of near term predictability and understanding climate variability and change. The scoping meeting may consider whether and how to assess research on seasonal to inter-annual predictions in the AR6.

Assessment of methods to combine multiple types of climate simulations: the AR6 will have to consider new high resolution global climate model outputs, large ensembles of simulations from individual climate models, simulations from different climate models (with sometimes a common genealogy), simulations from intermediate complexity models, and statistical and dynamical downscaling methodologies. There will therefore be a need for the AR6 to revisit model evaluation and assess the methodologies used in the literature to combine ensembles of climate simulations, including methodologies for bias corrections and downscaling. The AR6 report is expected to consider model development and the associated implications for the evolution of model performance and modelling approaches (e.g. ensuring the possibility to compare results from CMIP3/AR4, CMIP5/AR5 and CMIP6/AR6).

[9] *https://www.wcrp-climate.org/wgcm-cmip*

Information from paleoclimate archives: Emerging fields include transient variations from reconstructions and simulations (last 2000 years; comparing present and last interglacial trends; comparing deglacial trends); new knowledge on mean state and variability within past periods warmer than today (e.g. warm periods of recent interglacial periods, Pliocene) and associated Earth system responses (e.g. carbon cycle, ice sheets); new knowledge on past changes in water cycle; information on state dependency of climate sensitivity; drivers and mechanisms of abrupt changes in ocean circulation; response to volcanic forcing. New methodologies are developed where model behavior is benchmarked against past climate information to inform future projections for specific aspects (e.g. Antarctic ice sheet response to climate change, ITCZ shifts in response to changing SST patterns).

Climate and emission metrics: the AR6 is expected to revisit key climate metrics, for instance by assessing emergent constraints and new information on climate sensitivity. The AR6 is also expected to revisit emission metrics for a broad set of components from anthropogenic emission (as this is key to bridge with WGIII). New concepts and applications together with new estimates are available in the literature. Assessments of further developments and updates of the carbon budget approach can also be expected. Furthermore, responses in the carbon system to declining emissions and concentrations, as well as assessment of carbon dioxide removal methodologies have received more attention recently and will be a potential topic for assessment.

Large-scale circulation and modes of variability: Large-scale changes in ocean and atmosphere dynamics act as a bridge between changes in the energy content of the climate system (as a result of radiative forcing and global feedbacks), and regional changes. New knowledge is also emerging on drivers of large-scale changes in atmospheric and ocean circulation (e.g. Hadley cell, AMOC), from paleoclimate, present-day observations, theory, idealized simulations (e.g. aquaplanet) and projections from coupled climate models.

Further assessment of drivers and mechanisms of decadal variability, including the global nature of the associated atmospheric processes and mechanisms, is needed. New knowledge is emerging from analysis of observations as well as use of large model ensembles and initialized simulations. The attribution and quantification of the relative importance of internal variability and both anthropogenic and natural external forcing in driving the observed change at global to regional change is expected to be enhanced in the AR6, together with a critical evaluation of climate models regarding their performance in representing the characteristics of the major modes of climate variability. Finally, new results have emerged since the AR5 on characteristics in modes of variability (e.g. ENSO) in a changing climate. The assessment of knowledge on climate dynamics and modes of variability may thus be strengthened in the AR6.

Regional climate changes: Regional climate change and variability are the complex outcome of global climate change (including sea surface temperature characteristics, linked with large-scale changes in ocean circulation), large-scale atmospheric (e.g. jet stream, monsoon) circulation changes, and their interplay with local drivers (e.g. land surface, aerosols), local physical processes and the non-local responses to large-scale phenomena such as ENSO or other modes of climate variability. New developments towards improved regional scale information on future climate change is emerging from very high resolution global climate models (e.g. HighResMIP[10]), as well as coordinated sets of regionally downscaled regional climate projections through the WCRP CORDEX (Coordinated Regional Downscaling Experiment) activity and other downscaling initiatives. Open questions are associated with the selection of global climate model outputs driving regional modeling approaches, with the assessment of the strengths and caveats of statistical and dynamical

[10] *Haarsma, R. J., Roberts, M. J., Vidale, P. L., Senior, C. A., Bellucci, A., Bao, Q., Chang, P., Corti, S., Fučkar, N. S., Guemas, V., von Hardenberg, J., Hazeleger, W., Kodama, C., Koenigk, T., Leung, L. R., Lu, J., Luo, J.-J., Mao, J., Mizielinski, M. S., Mizuta, R., Nobre, P., Satoh, M., Scoccimarro, E., Semmler, T., Small, J., and von Storch, J.-S.: High Resolution Model Intercomparison Project (HighResMIP v1.0) for CMIP6, Geosci. Model Dev., 9, 4185-4208, doi:10.5194/gmd-9-4185-2016, 2016.*

downscaling methodologies, with the comparison of skills from high resolution global climate models. Model inter-comparisons at the regional scale are emerging from efforts such as CORDEX and their availability should be carefully considered in shaping the AR6 report. Similarly, research developments in the physical science realm are ongoing for assessing aspects of climate changes specific to cities, in the field of urban climatology (e.g. projected changes in urban heat island effect), high mountains or small islands. The assessment of uncertainties associated with regional information is particularly important.

Climate extremes and detection and attribution: the research field associated with extremes in a changing climate is evolving fast, with new analyses of observations, developments of methodologies for understanding processes and drivers of extreme events (e.g. in relationship to SST and atmospheric circulation patterns), and growing use of regional modeling and high resolution global climate modeling (e.g. for tropical cyclones). It will be important for the scoping of the AR6 to consider the definition of extreme events, associated with careful consideration of availability of high-resolution data. Limited efforts have been devoted to changes in relative humidity accompanying hot extremes in the AR5 and SREX, though it is recognized that the impacts of heat waves on human physiology and health would be substantially exacerbated by increasing relative humidity. Confidence in future changes related to tropical cyclones, droughts, and small-scale extremes remain low, so further assessment is particularly desirable in AR6. Finally, the AR5 and SREX mostly focused on extreme events over the land surface, with the exception of coastal submersion risks. New developments are also ongoing towards the identification of marine extreme events, and this may be considered in the AR6 reports (SROCC and WGI).

Since the AR5, significant progress has also been achieved in event detection and attribution techniques, including near real-time analyses that estimate human influence on the intensity and/or likelihood of various events. Methodological advances now allow to characterize the drivers of observed extreme events, by considering the relative influence of atmospheric circulation patterns, SST, and other processes in a probabilistic approach comparing frequencies, durations and intensities of events (e.g. heat waves, heavy rainfall) in a pre-industrial climate, versus the actual climate state. The detection and attribution perspective is also increasingly being explored to address the question of when the anthropogenic warming signal of climate change will emerge from the background noise of climate variability, referred to as the “time of emergence”. It is important for the AR6 to assess the state of knowledge with respect to the detection and attribution of extreme events, at the regional scale.

Sources of knowledge: the AR6 WGI report may benefit from knowledge provided by science epistemology (e.g. for the assessment of research developments, model evaluation) and social sciences (e.g. for comparing observed and perceived climate change), historical information and indigenous knowledge, especially for areas with limited pre-satellite instrumental records (e.g. Arctic snow cover, climate trends for e.g. high mountain or small islands), available from the literature. The WGI report may also consider opportunities to foster climate literacy and education of climate science.

E. Cross-cutting issues: links with Special Reports

Ensuring a coherent assessment process building on Special Reports

The IPCC Sixth Assessment Report (AR6), to be completed in 2022, will be produced in conjunction with a methodological report (Revised IPCC Guidelines for National Greenhouse Gas Emission Inventories) and three IPCC Special Reports focusing on, respectively: (i) the impacts of global warming of 1.5 ºC 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 (SR1.5); (ii) climate change and oceans and the cryosphere (SROCC); and (iii) climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (currently named SR2).

It is important to design the AR6 WGI report so that it will complement and update the assessments of the three special reports, without duplicating efforts and workload for the scientific community, in a coherent approach. For example, CMIP6 projections and model evaluation are expected to feature predominantly in the AR6 report.

From a WGI perspective, the SR1.5 is expected to assess the available literature relating regional climate change and impacts, as well as global sea level rise, to the level of global mean warming. It will also assess methodologies to relate a long-term climate target with emission pathways, accounting for the various sources of uncertainties.

Pending on approval of outline, the SROCC is expected to assess the observed changes in the ocean and the cryosphere and their drivers, develop the first assessment of processes associated with ocean and ice shelve interactions, assess specificities of climate change and high mountain as well as polar regions, assess new knowledge related to ocean heat and carbon uptake (including blue carbon) and sea level risks, assess the impacts of climate change on marine ecosystems, as well as marine extreme events and abrupt change.

Pending on approval of outline, the SR2 is expected to assess the state of knowledge with respect to the interplay between land cover, land use and the climate system, including greenhouse gas sources and sinks from terrestrial ecosystems, but also dust and other biophysical feedbacks.

Linkages with the Methodological report from TFI include revised emission inventories (e.g.: sources of methane emissions, carbon in soils).

A number of WGI issues will be cross-cutting across all reports, such as regional climate projections, sea level projections (relevant to SR1.5, SROCC, but also potentially for SR2 with respect to implications of regional sea level rise and salinization of aquifers for food production).

It is important to identify these cross-cutting issues during the AR6 scoping and design the WGI report to provide an update and a complement to the three Special Reports and the Methodological Report, when new knowledge is available (e.g. from CMIP6 projections). This is particularly important for WGI given the timeline for preparation of the AR6 report[11], as the approval of SR1.5 is scheduled after the first AR6, WGI lead author meeting, and the approval of SROCC and SR2 after the third AR6, WGI lead author meeting.

[11] *See http://ipcc.ch/activities/pdf/ar6_schedule.pdf*

Annex 1 – WGI AR6 pre-scoping questionnaire

The WGI co-chairs and TSU have elicited input from international research programmes related to climate science and former Coordinated Lead Authors and Co-Chairs of the AR5, WGI report on the structure and content of the Working Group I (the 'Physical Science Basis') contribution to the IPCC AR6. 60 responses were received by March 1st, 2017 and their synthesis is underway and will be provided with the next version of this background document.

Table 1: WGI pre-scoping questionnaire
1. In your vision, which are the main topics/questions that should be addressed in the AR6 WGI report? Please highlight emerging knowledge that you consider highly relevant.
2. Are there any potential overlaps or synergies with assessment reports being undertaken by other bodies?
3. Considering the chapter structure of the AR5 WGI report (**Appendix A**) do you have any recommendations for the chapter structure of AR6 WGI? (e.g. *adopting the AR5 structure, combining chapters, including additional chapters, or an alternative chapter structure*)? If so, why?
4. Considering the three Special Reports of the Sixth Assessment cycle (**Appendix B**), along with the WGII and WGIII contributions to AR6, please highlight WGI topics you view as requiring careful handling to ensure consistent assessment across reports
5. Do you have any recommendations for the treatment of WGI aspects of regional climate change within the AR6 report?
6. Has your organization used previous IPCC products (e.g. AR5, SREX) and if so, what for?
7. Do you have any other comments or suggestions?

Table 2: List of recipients organizations of WGI pre-scoping questionnaire
Analysis, Integration and Modelling of the Earth System (AIMES) (part of Future Earth) Arctic Contaminants Action Program (ACAP) (part of the Arctic Council) Arctic Monitoring and Assessment Programme (AMAP) (part of the Arctic Council) Association for the Sciences of Limnology and Oceanography (ASLO) bioDISCOVERY (part of Future Earth) Climate and Cryosphere (CliC) (Part of WCRP) Climate and Ocean - Variability, Predictability, Change (CLIVAR) (part of WCRP) Climate Change, Agriculture and Food Security (CCAFS) (part of Future Earth) Conservation of Arctic Flora and Fauna (CAFF) (part of the Arctic Council) Coordinated Regional Climate Downscaling Experiment (CORDEX) (part of WCRP) Forum of Arctic Research Operators (FARO) Future Earth Coasts (part of Future Earth) Global Atmosphere Watch (GAW) Global Carbon Project (GCP) (part of Future Earth) Global Climate Observing System (GCOS) Global Energy and Water Cycle Exchanges Project (GEWEX) (part of WCRP) Global Framework for Climate Services (GFCS) Global Land Programme (GLP) (part of Future Earth) Global Ocean Observing System (GOOS) Global Sea Level Observing System (GLOSS) Global Terrestrial Observing System (GTOS) Hydrology and Water Resources Branch Integrated Land Ecosystem-Atmosphere Processes Study (ILEAPS) (part of Future Earth)

Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) (part of Future Earth)
International Arctic Science Committee (IASC)
International Association for the Physical Sciences of the Oceans (IAPSO)
International Association of Cryospheric Sciences (IACS)
International Association of Hydrological Sciences (IAHS)
International Association of Meteorology and Atmospheric Sciences (IAMAS)
International Civil Aviation Organization (ICAO): Committee on Aviation Environmental Protection (CAEP)
International Geographical Union (IGU)
International Glaciological Society (IGS)
International Global Atmospheric Chemistry (IGAC) (part of Future Earth)
International Maritime Organization (IMO)
International Permafrost Association (IPA)
International Union of Quaternary Research (INQUA)
Monsoon Asia Integrated Regional Study (MAIRS) (part of Future Earth)
oneHEALTH (part of Future Earth)
Partnership for observations of the Global Oceans (POGO)
Past Global changes (PAGES) (part of Future Earth)
Protection of the Arctic Marine Evnrionment (PAME) (part of the Arctic Council)
Scientific Committee for Antarctic Research (SCAR)
Scientific Committee on Ocean Research (SCOR)
Stratosphere-troposphere Processes And their Role in Climate (SPARC) (part of WCRP)
Surface Ocean-Lower Atmosphere Study (SOLAS) (part of Future Earth)
Sustainable Development Working Group (SDWG) (part of the Arctic Council)
The Climate & Clean Air Coalition (CCAC)
The Oceanography Society (TOS)
Urbanization and Global Environmental Change (UGEC) (part of Future Earth)
WATER FUTURE (part of Future Earth)
Future Earth Global Hub Directors.

Contribution of Working Group II

Structure

1. **Point of departure**
2. **Framing for the AR6**
3. **Natural and managed systems and their uses**
4. **Human systems: health, well-being, security, settlements, industry, and infrastructure, adaptation-mitigation tradeoffs and feedbacks**
5. **Adaptation decision-making, governance and institutions, and economics: needs, options and limits, influencing factors and current practices**
6. **Multi-sector impacts, risks, vulnerabilities, opportunities and challenges**
7. **Sustainable development pathways: integrating adaptation, mitigation and sustainable development goals**
8. **Regional aspects [including cross-cutting for all WGs]**

1. Point of departure

The overarching premise of the IPCC Fifth Assessment Report (AR5) was the need to assess current and future risks from climate change through understanding of the vulnerability and impacts on natural and managed systems, industry and infrastructure and human well-being and societies. One of the major developments in AR5 was the expanded treatment of options and scope for adaptation as a means to reduce risk, reflecting a large increase in literature and the emergence of national climate-change adaptation plans in many countries. The adaptation chapters (Chps 14-17) consider needs and options, planning and implementation, opportunities, constraints and limits and economics. This emphasis on humans and the societal impacts of climate change in AR5 will be developed further in the Working Group II contribution to the IPCC Sixth Assessment Report (WGIIAR6). It is envisaged WGIIAR6 will have a strong focus on options for solution pathways.

The impacts of climate change on ecosystems, their conservation and management specific to sectors and regions, including risks to food security and related industries and communities, were also central to AR5. The impacts of climate change and interactions with anthropogenic stressors were assessed across natural and managed systems, including dryland ecosystems, forests, freshwater resources, permafrost systems, and agriculture, at global and regional scales. Risks for ocean ecosystems from coastal waters to open ocean and for oceanic regions with contrasting governance and management frameworks were emphasized through the addition of two new chapters (sectoral Chp 6 Ocean systems, regional Chp 30 The ocean). AR5 presented evidence of the link between climate change and impacts on food production systems (cropping systems, fisheries, and livestock production) involving issues such as soil health, water cycle, land degradation and biodiversity decline. All of these issues will be further assessed using new information in the AR6 assessment cycle. AR5 was the first assessment report with a standalone chapter on urban areas (Chp 8). Following the decisions at the 2015 Nairobi IPCC plenary, this treatment will be enhanced in AR6 through increased cross-working group interaction. The linkages between climate change, land degradation and desertification will be addressed in a Special Report due in 2019 with updates of the findings in the WGIIAR6.

WGIIAR5 summarized the detection and attribution of observed impacts, as well as the emergent (projected) risks and key vulnerabilities and climate-resilient pathways in two chapters (Chp 18-19). These chapters synthesized material from across the WGII report to provide a sharp focus on the aspects of climate change that emerged when the larger picture across many regions and sectors was considered. The recent expansion of the literature on climate change impacts is expected to strengthen the scientific understanding for WGII AR6, in particular, in regard to attribution issues. AR5 considered findings in deeper time (“paleo” and “historical”) to provide evidence of the sensitivity of terrestrial and marine ecosystems to climate change and the role of changes in climate in human conflicts. However, treatment of these issues was sparse and historical and paleo evidence was not comprehensively assessed in WGII, in contrast to WGI (which produced a separate chapter on information from paleoclimate archives). Accordingly, WGIIAR6 will expand on paleo and historical information by dedicated contributions.

In response to a growing demand for regional information on climate change impacts, WGIAR5 included one regional chapter and an atlas of climate projections for regions. WGIIAR5 produced regional chapters as an independent volume of the WGII report (Part B: Regional Aspects) which also drew on WGI material. The regional chapters were structured following the continents with three additional regions, polar regions, small islands and the ocean. WGIIAR6 will build on this approach for further integration of regional information which will be presented along with global information in a single volume.

2. Framing for the AR6

AR6 will build on AR5 and previous IPCC Assessment Reports with a strong focus on solution options at global and regional scales, with supporting evidence through the production of three Special Reports. WGII AR6 will assess the scientific literature covering the observed and projected impacts of climate change for ecosystems, industry and infrastructure and human societies. The vulnerabilities of these systems will be identified as well as the levels of associated risks and the system capacities for adaptation to climate change. A risk framework building on that of WGIIAR5 is planned for AR6 WGII.

WGII AR6 will build on the scientific literature covering natural and managed systems and their goods and services including their role in supporting food production systems and food security. Climate-induced challenges to both health and livelihoods combined with poverty may contribute to human conflicts and/or migration. Responses of human societies vary with the types of settlements, leading to the need to differentiate between urban and rural areas, their specific climatic conditions, associated livelihoods and levels of poverty. For human societies, this also involves their capacity to make the appropriate decisions on response options. Adaptation and mitigation responses involving industries and infrastructures also vary at regional and local scales, and understanding of the impacts and feedbacks among responses is required.

Social, psychological, cultural and ethical factors including production and consumption patterns influence decision-making by governance systems, institutions and individuals when choosing between and implementing adaptation and mitigation strategies. The best possible decisions will be informed by a community's needs, options and limits to adaptation, traditional practices and lessons learned. The capacity to overcome societal inertia will require consideration, as well as the need and differing approaches to balancing the costs of action and inaction. The economics of adaptation differs between societies, including trade and financing at various scales. Factors such as the unquantified risk to industries and financiers, and potential for economic diversification will be assessed as adaptation measures to increase economic resilience, leading to the identification of those policy options that support people, cities and economic activity to cope with the impacts of a perturbed climate.

Past societal responses to changes in climate, as well as information on extreme and repeated climatic changes' impacts on species and ecosystems on geological timescales can inform the development of appropriate adaptation and mitigation strategies. Information on historical and geological patterns can contribute to the detection and attribution of impacts presently observed across various regions, as well as to the identification of emergent risks and key vulnerabilities. Last but not least, these assessments will help frame sustainable development pathways, providing the information required to choose between adaptation and mitigation options, while facilitating sustainable development. Since the completion of IPCC's Fifth Assessment cycle in 2014 there has been a significant change in the international policy environment as a result of a series of global agreements that emphasize the commitment to sustainable and climate safe development. Agreements include:

- The 2030 Agenda for Sustainable Development and the associated 17 Sustainable Development Goals (SDGs)
- The United National Framework Convention on Climate Change's Paris Agreement which includes the legally binding goal to limit "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".
- The 2015 to 2030 Sendai Framework for Disaster Risk Reduction
- The 2016-2036 New Urban Agenda agreed upon at the Habitat III cities conference in Quito, Ecuador, in 2016

Earlier agreements include:

- The Convention on Biological Diversity (CBD) with the 2011 to 2020 Aichi Biodiversity Targets
- The United Nations Convention to Combat Desertification

These agreements provide context to the WGIIAR6, which will assess information on climate impacts and various adaptation strategies, considering exposure to climate trajectories that may either successfully reach the targets of the Paris Agreement or may fail to do so. In this way, the scientific information provided in the IPCC AR6 assessments will provide a framework and potentially useful information for the integrated implementation of the SDGs and the Paris Agreement and support an informed evolution of the international policy environment.

The following products of the AR6 assessment cycle precede the main assessment report and will provide a comprehensive, rigorous, and robust scientific assessment of these policy-relevant topics. They will help inform the contribution from WGII to the AR6 and include:

- Global Warming of 1.5^{o}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
- The IPCC Special Report on oceans and the cryosphere in a changing climate [title TBD]
- The IPCC Special Report on 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 [title TBD]

We see the need to limit the total number of chapters in WGII AR6 to a maximum of 20 while ensuring an appropriate number and range of expertise among authors who contribute to each chapter. As part of WGIIAR6 we shall incorporate regional chapters as was the case in the WGIIAR5 regional volume, i.e. Africa, Europe, Asia (Northern, Southern, Eastern, South-East and Western), Australasia (Australia, New Zealand), North and Central America, and South America, inviting WGII and WGI authors to contribute.

WGIIAR6 will strive to incorporate the recommendations of the 2016 workshop on communications.

3. Natural and managed systems and their uses

It is envisaged that the WGIIAR6 will quantify impacts and risks for natural and managed systems as well as increase our understanding of current status and trends together with projected impacts and risks. WGIIAR6 will also consider the timing and magnitude of adaptation responses necessary to inform policies and planning, including those responses with mitigation co-benefits. Knowledge gaps such as physiological limits to adaptation of crops, livestock, fish and other organisms, and uncertainty in regional ecosystem, fisheries and crop production models will be considered in WGIIAR6, and may be complemented with paleo evidence of vulnerability and risks. New knowledge on the impacts of extreme climate events should be assessed in the context of projected and slow onset changes in natural and managed systems.

Key questions regarding interactions among climate change, urban development, land use change, and human well-being will be addressed to inform where possible solutions might lie. WGIIAR6 will explore the basis for discussing new insights on the social and economic costs of loss (or gain) of ecosystem health, goods and services and the capacity and limitations for ecosystem-based and human-assisted adaptation. Impacts of changes in climate variability and climatic means have different and potentially conflicting implications for adaptation strategies. Knowledge gaps exist in terms of adaptation options and interactions with mitigation activities, as well as strategies for the

protection of ecosystems and conservation of biodiversity. Similarly, the issues of non-linearities, thresholds and natural variability in natural and managed systems as well as potential feedbacks in the Earth's system should be addressed. This includes potentially negative impacts of adaptation and mitigation measures on ecosystem health and ecosystem services across regions and sectors e.g., in the agriculture or water sector due to competition for land and water, in low-lying regions or high altitude mountains, in urban or rural areas, in developed or developing regions, or for disadvantaged or wealthy parts of the human population. For the ocean, the scope and potential of solution options available for and from ocean systems is yet to be assessed, such as technological advances for marine transport, nature-based adaptation and mitigation opportunities, and governance frameworks for managing across country borders, for example fisheries management, resource exploration and exploitation, shipping access and routes.

Risk framing will consider impacts and their key uncertainties and probabilities. Changing risks from climate change need to be evaluated given the projected regional growths in human populations and their relevance to and interactions with SDGs. Climate-induced changes in natural and managed systems are strongly linked to issues of desertification and land degradation, water availability and food security, human health and well-being, human security and migration. Besides the assessment of climate change impacts on food production systems, synergies between adaptation, mitigation and development in shaping systemic resilience should be considered. While climate change impacts may reduce food security, human-driven impacts of land degradation may exacerbate these problems, including negative feedbacks of adaptation and mitigation measures through land-use change (e.g., cropland expansion, deforestation) and changes in agricultural practices (e.g., intensification of production, fertilizer use). Challenges for finding solution options involve finding context-specific approaches that go beyond the mere increase of productivity, considering food access, quality and utilization. Adaptation-mitigation synergies to be considered include adaptation measures with mitigation co-benefits and tradeoffs with ecosystems and biodiversity risks.

4. Human systems: health, well-being, security, settlements, industry, and infrastructure, adaptation-mitigation tradeoffs and feedbacks

Urban areas are increasingly important in understanding climate change issues. Urban areas account for over 70% of global fossil fuel CO_2 emissions and are vulnerable hotspots of climate impact. The 21st century is widely referred to as the 'century of the city' in acknowledgement of the environmental, social and economic transformative power of cities. Globally 54% of the world's population already live in urban areas (in 2014) and it is projected that continued population growth and urbanization will result in 66% of the world's population being urban by 2050. 90% of this increase will be concentrated in Asia and Africa.

There has been a significant shift in international policy relating to cities since the completion of AR5, most notably through the negotiation and adoption of the New Urban Agenda at the Habitat III conference in 2016. This agenda envisages that cities and human settlements will play a key role in increased global efforts to adapt to climate change through local action. The New Urban Agenda also stresses that 'urban centers worldwide, especially in developing countries, often have characteristics that make them and their inhabitants especially vulnerable to the adverse impacts of climate change and other natural and human-made hazards'. The scale of ongoing urban expansion, and associated infrastructure and buildings that are yet to be built, therefore provide a challenge as well as a unique opportunity for cities to innovate and manage global climate risk. Cities and regions may also be powerhouses of ambitious adaptation and mitigation measures, including those related to economic diversification, that are difficult to legislate and implement at the national level. Urban areas are therefore increasingly key to realizing the goals of the Paris Agreement and to 'strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty'. There is thus a need to advance the understanding of climate change risks at sub-national levels, as well as the opportunities and

impediments to adaptation action, and to develop a more complete understanding of how adaptation and mitigation co-benefits can be aligned at the local level. This will require better insights into the vulnerability and adaptation potential of individuals, communities and infrastructure (to both slow and rapid onset events) across a range of potential social, economic, political and technological trends and changes.

Rural areas are home to about 70% of the developing world's poor people. WGIIAR5 highlighted that in rural areas climate change will take place in the context of many important economic, social and land-use trends. There is a great diversity of rural areas and rural-urban relationships become increasingly complex and difficult to understand. Thus, for WGIIAR6, a differentiated consideration of rural-urban linkages is relevant. Rural populations are particularly vulnerable to climatic conditions and, as highlighted in WGIIAR5, major impacts will be felt through changes in water supply, food security and agricultural incomes. WGIIAR6 will therefore provide an integrative view that links the vulnerabilities of rural populations to changes in the coastal and terrestrial biosphere including issues related to land use, land use change and competition for land as well as the forces driving urbanisation. Strengthening adaptive capacity and thereby overall societal resilience in rural areas is also considered to form a critical element in the solution options to address climate change.

WGIIAR5 already showed the multiple causes and impacts—direct and indirect (e.g., extreme weather, cultural loss)—as well as different dimensions of climate change impacts on human security. Human security refers to processes on various spatial and temporal scales, e.g., developments in the global north are linked with those in the global south. Geopolitical dimensions including large distance migrations therefore need to be considered. For WGIIAR6, issues of human security such as ethical dimensions and their integration will be assessed, notably how to minimize cascading and amplifying effects of climate change, as well as irreversible impacts and the associated losses of resources, ecosystems, and infrastructure. Besides impacts on ecosystems, the potential loss of less tangible issues fundamental to societies such as landscapes, places (e.g., neighbourhoods), cultures, and social cohesion need to be considered. Integrating human and natural sciences, linking to food security, biodiversity and regional differences will address the complex nature of impacts and adaptation options. Methods include quantitative approaches towards risks and impacts and qualitative approaches of understanding and explaining human behaviour and psychosocial conditions.

Human migration is strongly linked to human well-being as critically determined by security issues, food security, land use change, and health. Human migration is of relevance not only for the global south and SIDS, but also for countries of the global north which are both directly and indirectly affected. Climate-induced migration is often presented in a negative context or even described as a threat. The role of migration as adaptation is becoming more and more recognized as an important element of addressing climate change. However, while there are wide-ranging discussions of climate-induced migration, there is a lack of commonly agreed definitions and related legal frameworks. Further gaps that WGIIAR6 will aim to close include how climate-related extreme events and slow onset events affect migration patterns, the causes of, consequences, and conditions for resettlement, as well as a recognition of the wide range of types of migration (e.g., voluntary vs. forced migration, rural-rural, or rural-urban).

5. Adaptation decision-making, governance and institutions, and economics: needs, options and limits, influencing factors and current practices

AR6 will extend the focus on adaptation to assess the increasing understanding of factors that influence decision making and whether and how decisions are implemented. This is critical for supporting the design and effective operationalization of appropriate response strategies. There is a wide range of factors that have been identified in recent literature including social, psychological, cultural, and political dimensions. Patterns of production and consumption for example are embedded culturally as well as economically and politically, and can also be understood in terms of intrinsic and extrinsic psychological needs. There is also an ethical dimension to decision-making - a

particular response strategy may have different consequences for different stakeholders, human as well as industry and ecosystem. Responses may be highly beneficial for one group but less positive or even maladaptive for another, which raises important issues of social and inter-species equity and justice. This is due to factors that interact with each other in complex non-linear ways, and which are context-specific.

Economic activity (trade, finance, development, consumption) will need to balance adaptation responses to a warmer world with emission reduction. Accordingly, WGIIAR6 will document the evidence for a global economy that supports (i.e., incentivizes and rewards) behaviour that is consistent with climate adaptation and balanced with mitigation activities, for example, considering information where the employment and investment benefits of adaptation programs are tracked. Evidence of maladaptation also needs to be documented. WGIIAR6 will highlight the literature documenting features of various types of economies, their effectiveness and likely effectiveness in coping with 1.5°C or 2°C and higher levels of warming. The relationship between economic equality (within and between countries, ethnic groups and gender) and adaptive capacity will be assessed.

WGIIAR6 should identify trade and finance approaches that support adaptation and highlight examples where trade and finance undermine adaptation. Issues include social and other environmental impacts of imported manufactured goods, and international finance (i.e., allocations of public and private capital) supporting adaptation while avoiding mal-adaptation (including deforestation, wetland draining, poorly located urban infrastructure). WGIIAR6 will make efforts to assess country-level aggregates of cost and benefit together with the estimation methods for global adaptation needs and costs in addition of estimating costs of impacts of extreme events and loss of ecosystem services. A focus will be on the literature that documents factors such as the synergies among adaptation and development (and implications of not taking these opportunities), as well as the rising cost of adaptation when natural resources are degraded or when economic planning ignores climate change. This includes considering the need to adapt and the evidence showing how adaptive economies fare in the face of shocks and over long-term trends.

6. Multi-sector impacts, risks, vulnerabilities, opportunities and challenges

WGIIAR6 will build on WGIIAR5 and address key knowledge gaps in assessments of multisector-impacts. Knowledge of ecological and societal responses to changes in climate over a wide range of time scales, from decades to millennia, offer insights for vulnerability and attribution of climate change impacts and adaptation options. WGIIAR6 will draw on evidence of ecological and societal responses to the magnitude, rates and duration of past changes in climate to inform understanding of risks from current and future rates of change, the rates of response, and tipping points or thresholds. The regional and broader global consequences of past climate events, including extreme climatic events, have implications for current actions towards SDGs and governance frameworks. This section also offers opportunities to capture other forms of knowledge, e.g., indigenous and local knowledge, not broadly assessed in previous ARs.

The assessment of emergent risks and key vulnerabilities, linked to projections of climate change, requires unifying approaches, e.g., in risk assessment across WGIIAR6 and WGIII AR6. Projected climate change impacts, risks and vulnerabilities are and will be unequally distributed, and certain (unique) systems are threatened more than others. Accordingly, there are various response options, which need to be embedded in poverty reduction and related SDGs. Further challenges include development of adaptation pathways which balance sustainable production and consumption with trajectories of economic development/growth.

7. Sustainable development pathways: integrating adaptation, mitigation and sustainable development goals

Adaptation and mitigation responses are often interlinked and implications for SDGs have not been broadly assessed. For example, adaptation and mitigation responses may or may not be aligned with SDGs, or they may be aligned with certain goals but in conflict with others. The integration of mitigation, adaptation and sustainable development is a high priority for WGIIAR6 given the pressing need to inform strategies and actions. The most pressing need is the identification of solutions that combine sustainable development pathways with equitable and ethical outcomes (considering distributional impacts arising from response options), and that enhance the resilience of vulnerable groups. These challenges will need to be addressed across WGII and III.

Detection and attribution is important for the validation and understanding of observed impacts on natural and human systems and enhances confidence in the projection of future impacts. Detection and attribution is therefore relevant to reduce uncertainty in decision-making. WGIIAR5 provided a comprehensive assessment of the state of knowledge, however, knowledge gaps in detection and attribution of observed impacts exist for many countries and for many natural and human systems. Assessment of the recent literature on methodologies for attribution will require the inclusion of qualitative as well as quantitative forms of evidence. The advancement of efforts since WGIAR5 by the physical climate community to attribute local and short-term (e.g., extreme) climate events to anthropogenic climate change also widens the scope of WGIAR6.

The move to sustainable development pathways needs to consider implications of the pursuit of the 1.5°C target, to be assessed in the Special Report on Global Warming of 1.5°C. Transformations may involve large scale feedbacks that could potentially compromise the achievement of SDGs in certain areas. Knowledge and experiences from local to global approaches, including case studies and integrated planning, will be included in WGIIAR6. There is a need to assess the conceptual and methodological understanding of the interactions among the multiple drivers of development pathways and the impacts and risks from climate change including thresholds and tipping points. Issues to be addressed include questions such as how climate change responses represent opportunities for innovative development paths, how to identify strategies for institutional development such as decision-making under uncertainty and how to provide evidence that facilitates the implementation of desirable changes and builds social inclusiveness?

8. Regional aspects [including cross-cutting for all WGs]

The regional chapters will ensure consistency in the treatment of concepts that are common to WGI, II and III, such as risk, vulnerability, adaptation, detection-attribution, extreme events, and mitigation. In line with the need to limit the total number of chapters in WGIIAR6 to a maximum of 20 while allowing for the best possible combination of authors to contribute to each chapter, it is proposed that WGIIAR6 applies a similar treatment of regions as in the WGIIAR5 regional volume, i.e. Africa, Europe, Asia (Northern, Southern, Eastern, South-East and Western), Australasia (Australia, New Zealand), North and Central America, and South America. Where available for assessment, sub-regional information will be captured, for example regionally specific and unequal adaptive capacities and socioeconomic preconditions. Cross-cutting issues that sit across multiple regions, may be considered in cross-chapter boxes of the regional report section. These boxes could follow a structure according to actual climate zone, functional or landscape criteria and may include biodiversity hotspots, freshwater supplies, deserts and arid areas including desertification and land degradation, tropical forests, Antarctic and Arctic regions, small islands, and mountainous areas.

Each regional chapter will include specific climate observations and projections, vulnerabilities and impacts on ecosystems (terrestrial, freshwater, marine) and their uses and management, built environment, industry and infrastructure and human systems. Regional chapters will present knowledge of adaptation and mitigation activities (implemented and potential) and interactions among activities and development goals for that region. The regional climate scenarios provided by

WGIAR6 will be used for the regional assessments by WGIIAR6, e.g., shifting eco-zones, species migration, desertification, extreme climatic events, coastal erosion and flooding, and associated consequences for human and managed systems. Regional ecosystems may differ in their vulnerabilities (e.g., general food security, water availability, disasters and natural hazards) and "tipping points" over different scales as well as in the nature of critical feedbacks between local, regional, and global processes. Teleconnections between regions may exist, e.g., climate changes, land use changes or shifts in water uses in one region may have implications for ecosystems in neighbouring regions. The regional section of the report also provides space to include opportunities for transboundary adaptation (e.g., integrated water resource management) and case studies. Together with WGIII, regional chapters will explore region-specific opportunities and limits to mitigation as well as adaptation mitigation trade-offs.

The regional chapters allow focus on factors contributing to human causes of climate change and factors affecting human vulnerability, adaptive capacity and resilience, which often vary widely between and within regions (e.g., governance models, cultural worldviews, economic health, gender roles, consumption patterns, land use). Such contextual factors have a significant influence on which adaptation responses are chosen and how they are implemented, and on the outcomes, that ensue. New literature on these topics offers the possibility for a more comprehensive treatment, supporting decision-making at local, subnational, and national levels. However, it should also be remembered that contextual factors are dynamic and the decision-making landscape can change very quickly. Context-specific approaches are well-suited to incorporate situated knowledge such as indigenous knowledge and community-based adaptation practices. The socio-economic consequences of economic activities and actions in terms of climate mitigation (e.g., biofuels and their links to competition for land, food and livelihood securities) can be and is best captured at regional scales.

The regional section allows further treatment of trans-regional societal phenomena (e.g., global trade and financial flows, migration) which are important for understanding potential solutions. Our understanding of such links between impacts, risks and adaptation options across regions is very much in its early stages. However, the regional section of the report provides opportunity to capture relevant advances since AR5, also through the characterization of uncertainties at national and regional scales. The regional chapters also allow a context-specific assessment of adaptation mitigation co-benefits and potential for maladaptation and of the role of national and regional governance in adaptation.

Contribution of Working Group III

B.III.1 Introduction

This section sets out the vision of the WG III Co-chairs and the WG III Bureau for the WG III contribution to the IPCC AR6.

Section B.III.2 looks back at IPCC products developed by WG during the AR5 cycle including the main AR5 repot and the Special Report on Renewable Energy (SRREN). It summarises key findings and messages from the two reports and goes on to consider responses that have subsequently emerged in the literature and elsewhere as well as identified gaps.

Section B.III.3 sets out the high level aspirations for AR6, from the perspective of the WG III Co-chairs and Bureau. Section B.III.4 then sets out the suggested elements of the AR6 report without proposing a specific structure. Finally, Section B.III.5 briefly outlines the proposed response for improving the communication of the WG III report.

B.III.2 Lessons from AR5

Scientific findings and main messages from the WG III AR5 Report

This section summarises the key findings and conclusions of the WG III AR5 report, focusing to a greater extent on the Summary for Policymakers. The 16 Chapters of the AR5 report were broken into six main sections: 1) the introduction; 2) a set of three "framing" chapters covering topics such as risk, ethics, equity and sustainable development; 3) a retrospective chapter looking at current and past emission trends and drivers; 4) a chapter assessing the literature on global integrated assessment modelling of emissions over the 21st century; 5) six sectoral chapters covering energy supply, demand sectors and AFOLU; and 6) four chapters covering governance, institutions and policy at three levels – international, regional and national/sub-national – plus a cross-cutting chapter on investment and finance.

The balance of material in the SPM was different from that in the underlying report. The "top-down" chapters (drivers and trends; pathways) accounted for 13% of the main report but 43% of the SPM. The sectoral material in the SPM was roughly commensurate with that in the underlying chapters but it did rely to some extent on cross-sectoral material drawn from the pathways chapter. The framing chapters and those on policies received proportionally less attention in the SPM.

	Chapters	**SPM**
Introduction	3%	2%
Framing	15%	8%
Driver and Trends	5%	13%
21st century pathways	8%	30%
Sectors	41%	34%
Institutions and policy	27%	13%

Unlike the WG I AR5 report, the WG III report did not make use of "headline" statements to summarise each section of the SPM, but started each of 81 paragraphs with a bolded statement. For the sake of space in this document, and only for that purpose, the following higher level messages are drawn from the presentation used at the WG III AR5 press launch. This is derivative material which was not specifically approved in plenary.

- GHG emissions accelerate despite reduction efforts. Most emission growth is CO_2 from fossil fuel combustion and industrial processes.
- GHG emissions rise with growth in GDP and population; long-standing trend of decarbonisation of energy reversed.
- Without more mitigation, global mean surface temperature might increase by 3.7° to 4.8°C over the 21st century.
- Mitigation requires major technological and institutional changes including the upscaling of low- and zero carbon energy.
- Delaying mitigation is estimated to increase the difficulty and narrow the options for limiting warming to 2°C.
- Estimates for mitigation costs vary widely, but estimates increase with the stringency of mitigation.

- Mitigation requires changes throughout the economy. Efforts in one sector determine mitigation efforts in others.
- Substantial reductions in emissions would require large changes in investment patterns.
- Since AR4, there has been an increased focus on policies designed to integrate multiple objectives, increase co-benefits and reduce adverse side-effects.
- Effective mitigation will not be achieved if individual agents advance their own interests independently.

By the press launch, the findings from the framing chapters were, for example, compressed into the slide supporting the final statement.

Many of these statements are very high level. Of the 81 bolded statements in the SPM, the following (paraphrased by the authors of this document) have either attracted particular attention, or the topic they cover has been particularly debated or influential:

- Climate policy intersects with other societal goals creating the possibility of co-benefits or adverse side-effects.
- Scenarios consistent with temperature change below 2°C include substantial cuts in emissions by mid-century through large-scale changes in energy systems and potentially land use
- The Cancún Pledges are consistent with cost-effective mitigation trajectories that are unlikely to limit temperature change to 2°C
- Delaying mitigation efforts beyond 2030 is estimated to substantially increase the difficulty of the transition to low longer-term emissions levels and narrow the range of options consistent with maintaining temperature change below 2°C
- Only a limited number of studies have explored scenarios that are more likely than not to bring temperature change back to below 1.5 °C by 2100
- Mitigation policy could devalue fossil fuel assets and reduce revenues for fossil fuel exporters, but differences between regions and fuels exist.

Finally, a number of countries expressed their substantial disagreement with, and would not consider ourselves bound to the use of, the income-based country groupings used in parts of the WG III AR5 report and which were removed for the SPM during approval. A substantial amount of text on mitigation policies and institutions was also removed from the SPM.

Scientific findings and main messages from the SRREN

The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) was approved in 2011. Much of the report was concerned with the detailed assessment of six classes of renewable energy sources covering: resource potential; technology status and applications; market and industry development; integration into energy systems; environmental and social impacts; prospects for technology improvements and innovation; cost trends; and potential deployment. The six classes of energy source were: bioenergy; direct solar energy; geothermal energy; hydropower; ocean energy; and wind energy.

In addition, four cross-cutting chapters covered: integration into present and future energy systems; the sustainable development context; an assessment of mitigation potential costs taking into account system level perspectives; and policy, financing and implementation.

AR5: responses and gaps

Responses

The source of this section is both published literature and less formal feedback received, in the latter case much of it from policymakers. The authors of the document neither agree not disagree with the points made. They are reported for consideration during the scoping process.

A number of policymakers have expressed, through informal routes, some dissatisfaction with the framing chapters 2-4 of AR5 which relied on more theoretical literature from the social sciences and the humanities. There appears to be more than one element to this. First, some felt they were being lectured as to how to structure their thinking about responses to climate change which felt close to being policy prescriptive. Second, policymakers were most interested in what they saw as the "practical" elements of the AR5 report which began with chapter 5 – the framing chapters interrupted the flow. A third point to bear on mind when scoping AR6 is that the literature on the more theoretical elements covered in the framing chapters may move quite slowly. In some areas, there may be little additional literature to cite in AR6. It also raises wider issues about the type of social science literature that might be assessed and the balance between theoretical and applied elements.

There has also been pushback against the dominance of IAMs in the messaging of the SPM and subsequent derived material. This pushback stems from several factors:

- The perceived lack of transparency surrounding the assumptions and structure of the IAMs underpinning the assessment of global emission pathways. There has been a robust response to this from the IAM community.
- The relative lack of attention to national and regional modelling in favour of global models.
- Weak linkages between global modelling on the one hand and bottom-up perspectives/sectoral perspectives on the other`. This partly informed the proposal for a Special Report which has been taken forward with the Expert Meeting on *Mitigation, Sustainability and Climate Stabilization Scenarios.*
- Insufficient attention to the sustainability implications of the large scale deployment of GHG removal technologies, notably bioenergy with carbon capture and storage (BECCS). Again, this informed the Special Report proposal.

There have also been comments about the communications aspects of AR5 in terms of both graphical presentation and complexity of the language.

Gaps

This section is based on the subjective views of the document authors. The points raised in the previous section also imply gaps which are not addressed further here.

There was little treatment of fossil fuels in AR5. The role of natural gas in energy markets is a topic which will need attention in AR6 for a number of reasons: a) it has been cited extensively as an option for reducing GHG emissions in the medium-term ("bridge fuel"); b) the exploitation of shale gas in the US has influenced global gas markets and has brought down costs; c) there are unresolved issues about methane emissions from the natural gas supply chain which are of joint concern to WG III and the TFI. A further literature has emerged round the concept of "unburnable carbon", the notion that the exploitation of available fossil resources is not compatible with low emission pathways.
Although renewable energy was well covered in the AR5 cycle, there have been significant developments requiring attention in AR6, notably large reductions in costs and the rapid deployment of wind and especially PV.

Somewhat contrary to the AR5 messaging, global CO_2 emissions have actually fallen in some recent years; emissions have started to decline in many developed countries and there is the prospect of peaking in some emerging economies. Literature on these trends and their drivers will need to be assessed.

The literature on wider sustainability implications of low emission pathways will need to be assessed, especially now the Sustainable Development Goals (SDGs) provide a structured and internationally endorsed framework for doing so. Both the ecological aspects (e.g. impacts of mitigation responses on ecosystem services and biodiversity), and the socio-economic implications and opportunities (e.g. economic diversification in resource-rich economies) will need to be addressed.

Finally, in the light of the ambition expressed in the Paris Agreement, there will need to be attention to technologies and other methods for enhancing GHG sinks (GHG removal or GGR) with a view to achieving net zero emissions. The question of how WG III might assess literature on solar radiation management (SRM) options in cooperation with other WGs should be discussed at the AR6 scoping meeting.

B.III.3 Framing the WG III contribution

Whatever the overall chapter structure, there has been, and there always will be, a need for an introductory chapter that sets out how the report is structured and how the authors will pick their way through the literature relevant to the mitigation challenge. In thinking about the problem *framing* developed in the introductory chapter, we go back to basics and remain ourselves of what IPCC was set up to do:

- "to prepare, based on available scientific information, assessments on all aspects of climate change and its impacts, with a view of formulating realistic response strategies"
- The initial task…. was to prepare a comprehensive review and recommendations with respect to the state of knowledge of the science of climate change; the social and economic impact of climate change, and possible response strategies

The specific mention of *all aspects* of climate change and *a comprehensive review* points to the need to ensure that all strands of literature relevant to policymakers are assessed. This in turn suggests the need for caution in framing the WG III report. Different strands of literature may themselves frame the climate mitigation challenge in different ways. In the social sciences, humanities and economics these different framings may indeed compete with each other in the sense that they provide alternative ways of looking at the same issues. Cost-benefit analysis, risk assessment and analysis, systems/scenarios are all examples of ways that the mitigation challenge might be framed and there is ample literature to assess in each of these domains,

It is therefore important to ensure that the WG III report does not adopt a single framing that may exclude some strands of literature relevant to policymakers. Just as IPCC must be "policy relevant but not policy prescriptive", it should also not prescribe ways of framing or thinking about climate change mitigation that lead to strands of literature that might benefit policymakers falling outside the scope of the assessment. The challenge of the introductory chapter is not to frame the mitigation challenge in any particular way: it is to *frame the framings*, i.e. identify the main strands of relevant literature, make transparent the underlying assumptions, identify the strengths and limitations of each strand, set out the questions relevant to climate mitigation which they can be used to address and explain how the literature will be assessed across the report.

Overarching aims of the WG III contribution

WG III has addressed a number of issues over the last IPCC cycles such as: a) mitigation costs; b) technical, economic and market mitigation potentials; and c) policy -making and co-operation at different scales. We anticipate the WG III AR6 report will continue to cover these aspects. Following on from the approach to framing and reactions to the AR5 report, we have identified three high-level over-arching objectives for WG III in AR6 that build on previous contributions:

1) ***to achieve a better synthesis between higher-level "whole system" perspectives derived from, for example, global integrated assessment models (IAMs) and grounded, bottom-up insights into technologies and other approaches for reducing emissions***. IAM modelling dominated the messaging of the WG III AR5 report. The role, the construction and the transparency of the assumptions underlying these models has since been challenged. IAMs will continue to be an essential tool for analysing mitigation opportunities from an integrated, whole system perspective but better two-way communication with other approaches, and the development of metrics that will enable more effective communication, are essential.

2) ***to make greater use of social science disciplines, in addition to economics, especially for gaining insight into issues related to lifestyle, behaviour, consumption, technological choices and socio-technical transitions***. The social sciences have played a modest role in IPCC so far but are needed to address the more profound economic and social change that could be implied by ever more ambitious climate ambition. The social sciences can inform action at the national level by assessing: a) how consumption patterns and lifestyle could affect emissions; b) how these patterns might be influenced; and c) decision-making in relation to the adoption of technologies and practices. Applied social science can provide insights into "what works" in policy terms. Political scientists can address the design and effectiveness of international cooperation arrangement.

3) ***To link climate change mitigation better to other agreed policy goals nationally and internationally.*** The WG III AR5 report started to deal with the "co-benefits" associated with climate mitigation measures, such as air quality improvements and energy security and, to a lesser extent, the risks. The UN Sustainable Development Goals (SDGs) provide a new context for addressing co-benefits and risks. Eradicating poverty and enhancing food security have been particularly emphasised by developing countries. The AR6 report needs to take account of specific SDGs such as number 7 on affordable and clean energy and number 1 on ending poverty. It should also take account of the inverse relationship whereby some policies and actions will be pursued primarily precisely because of the "co-benefits" (e.g. improved air quality) with climate change mitigation being the fortuitous outcome.

In respect of the three overarching objectives, we would note that WG III has in the past, tended to restrict itself to global perspectives when it comes to sectors and mitigation technologies and practices. These three objectives offer the potential for WG III to increase the emphasis on regional aspects. Some aspects may indeed only be meaningful if a regional perspective is taken. For instance, the rates of change and barriers to the uptake of mitigation technologies practice may be regionally specific and may manifest themselves only at a regional scale. Issues related to behaviour, consumption and socio-technical transitions are also likely to be regionally specific. Finally, assessing climate-sustainability links has little meaning at a global scale. Assessable literature is available at a regional scale and WG III will explore the possibility of including this during the scoping process.

B.III.4 Proposed elements of the WG III AR6 report

The WG III Bureau does not propose a specific structure for the AR6 report. Instead, we propose potential *elements* of the report which could be combined in different ways to arrive at a chapter structure. Within the complex challenge of climate change mitigation, everything is connected to everything else. There is no single "correct" way of structuring the WG III report: the challenge is to arrive at one of many possible structures that remains true to the underlying scientific literature while meeting the needs of policymakers.

Notwithstanding the high-level objectives set out above, the sectoral chapters remain the "bread and butter" elements of the WG III report and are underpinned by a vast literature, largely in the engineering, physical sciences and techno-economic sphere, that covers cost, performance, deployment potential and other factors. Non-sectoral chapters will need to address emerging technologies and innovation, whole systems perspectives and cross-cutting issues such as policy, lifestyles/behaviour/ consumption, climate finance and technology co-operation.

Framing and context

Framing. We suggest that an introductory chapter which "frames the framing" of the mitigation challenge in different literatures, sets out how these literatures are addressed in the report and sets out the structure and narrative of the report is essential.

Climate change mitigation and sustainable development. The report would need to address the co-benefits and risks associated with climate change mitigation and the implications for sustainable development, poverty eradication, food security and biodiversity. Some mitigation measures may themselves have sustainability consequences. An example is BECCS which, at the high levels of deployment suggested in some IAM models, would have land use consequences including the availability of land for food production. The report should also address the consequences in terms of climate change mitigation of policies and actions undertaken to support the SDGs. The new UN SDGs and the growing literature associated with them will be an important lens through which to address this theme.

Trends and Drivers. The report would need to address trends in GHG sources and sinks since AR5, the underlying socio-economic and technical drivers and the way human that responses have influenced sources and sinks.

Monitoring progress. The report would address facilitative actions that inform ambition, track pathways towards Paris Agreement aims and related solutions.

Whole systems approaches

As in AR5, and driven by the need to connect mitigation responses, which may be national and subnational, with the global ambition expressed in the Paris Agreement, there is a need to look forward and assess emission pathways and mitigation opportunities over the 21st century at a macro-level, making use of global integrated assessment models (IAMs). However, the WG III Bureau would like to see global IAM modelling complemented by regional and national modelling, and by sectoral models. WG III is currently organising an expert meeting on *Mitigation, Sustainability and Climate Stabilisation Scenarios* to tease out the links between global level perspectives on the one hand and national/regional/sectoral perspectives on the other. This assessment will need to consider issues such as: the timing of responses, the feasibility of ambitious mitigation pathways (e.g. costs, scale and speed of response, degree of lock-in/stranded assets, institutional capacity etc.) in a scientifically framed manner, and the wider co-benefits and risks.

Sectoral elements

There are good reasons for making the core of the AR6 report a set of sectoral chapters covering energy, land and human settlements: a) it would map on to the structure of the emissions inventories which Parties report to the UNFCCC; b) it would provide a background for monitoring progress; and c) it would also map on to indicators and targets identified in many NDCs, examples of which include targets for renewable energy deployment or rates of afforestation. Within each of the sectoral areas, the emissions include both energy-related CO_2 emissions, which constitute the majority of GHG emissions, and other GHGs.

Energy supply. Since the WG III AR5 report took shape in 2011-12, the global energy system has changed and this has begun to be reflected in the literature. Energy consumption appears to have been decoupled from economic growth and is projected to fall in developed economies. The re-direction of the Chinese economy away from heavy industry has played a role in this change. At the same time, there have been significant developments on the supply side. First, unconventional gas has revolutionised US energy supply with spill-over effects into international energy markets. Where gas has displaced coal, this has reduced GHG emissions (though there is controversy about methane emissions from gas production). However, whether gas is a "bridge" to a low carbon future or could lock out very low or zero carbon energy supply in the longer term is the subject of analysis and debate. Second, the fall in the cost of renewable energy, especially solar and wind, and the rapid progress in penetrating energy markets has been extraordinary. More than half of all new electricity generating capacity globally was renewable in 2015; China now gets more power from wind than from nuclear. The third factor has been the fall in the oil price. This is related to the fossil fuel revolution in the US (light tight oil as a well as shale gas) but also to wider geo-political factors. These factors interact. Low fossil prices change incentives for climate change mitigation and have now themselves become the subject of study.

Energy demand. Key sectors relevant to the energy demand side include human settlements (especially cities), built environment, transport and industry. The report will need to address higher level issues such as urban design and planning. These could, in turn, be used to frame assessments of literature focused more specifically on buildings and transport. Cities are now a major focus of mitigation research and climate action. An industry chapter could include more systemic elements such as the contribution of circular economy concepts, resource efficiency material substitution and dematerialisation to mitigation.

The energy system. There is a growing interest in how the convergence of information and communication technologies (ICT) and energy technology, coupled with novel business models, could transform relationships between energy producers and consumers. The term "smart" may be ambiguous, but smart grids, meters and thermostats are now firmly part of the landscape. The literature on these systemic issues will need addressed.

AFOLU. Under the IPCC emissions inventory guidelines, agriculture, forestry and land use (AFOLU) is considered a distinct sector. AR5 had a single chapter with an Annex on bioenergy. Given that the scope of AFOLU is very large, consideration might be given to separating out treatment of the different elements including a focus on non-CO_2 gases. Many aspects could be dealt with in the Special Report on issues relating to land use for which WG III has the operational lead. The division of the AFOLU agenda between the Special Reports and the main AR6 report needs to be addressed in the scoping process.

Food systems. The AR5 approach to food was essentially supply-oriented with little emphasis on supply chains and demand-side issues such as diet. This is a potential element to be considered in AR6.

Cross-cutting elements

Emerging technologies and innovation. Since AR5, there has been a growing interest in novel approaches to mitigation that include "negative emission technologies" (NETs) that remove CO_2 from the atmosphere. Bioenergy with carbon capture and storage (BECCS) was heavily cited in the high-level emission pathways/modelling chapter in AR5 but there was little attention to performance, RD&D needs, deployment from a bottom-up perspective and the risks associated with its deployment (e.g. food v fuel issues). Other NET approaches include direct air capture (DAC), ocean fertilisation, biochar, soil carbon sequestration and enhanced weathering. Addressing the issue of "emerging technologies", including the sensitive topic of solar radiation management (SRM), in this chapter also seems to be essential.

Human behaviour and consumption. The role of lifestyles/behaviour/consumption in relation to climate change mitigation received relatively little attention in past IPCC reports. Important elements include consumption-based GHG emissions, insights into how social practices and patterns of economic development shape GHG emissions and how interventions can promote climate change mitigation. This would entail an "actor-oriented" approach requiring authors to draw to a greater extent on social science literature.

Policies, institutions and governance. The WG III AR5 report had three policy chapters focused at the national, regional and international levels. We would like to consider reducing these to two elements: the first covering the actions of UNFCCC parties within their own sovereignty; and the second covering how parties interact through the Convention and other international mechanisms. We would aim for a strong "what works" element by looking at literature that examines policy successes and (more delicately) policy failures.

Finance. The Paris Agreement contains specific elements on finance and technology development and transfer and we propose covering these explicitly. Economics and the social sciences will make a substantial contribution here.

Types of literature

WG II has made ample use of case studies in previous assessment reports. WG III would like to make more use of case studies in AR6 to provide examples of measures that may assist policymakers in spreading good practice while reconciling the goals of climate change mitigation, sustainable development and economic diversification.

B.III.5 Links to other Working Groups and the Task Force on Inventories

This Section should be read in conjunction with Part C of this document. There are two main types of linkage between WG III and the other Working Groups and with the Task Force on Inventories:

a) When there are interdependencies, but not overlaps, between the work of scientific communities operating within the domains of different WGs;
b) When specific topics overlap or cut across different scientific communities and in principle could be dealt with by more than one WG.

This section addresses both types of linkage. IPCC has several mechanisms available for dealing with these linkages including: expert meetings; cross-WG authors; cross-cutting teams operating across WGs; lead authors working on chapters in different reports; contributing lead author roles across WGs; and cross-referencing between reports. A convergence across WGs on the use of terminology such as co-benefits, risks, trade-offs, synergies etc. would be valuable. However, this section does not propose specific solutions to these issues.

It would also be useful to review, across WGs, the current IPCC uncertainty guidance. The way this was interpreted in AR5 resulted in some communication challenges for WG III, especially in relation to the reporting of IAM results.

Working Group I

The link between climate scenarios and the scenarios associated with integrated assessment models (IAMs) is a critical point of contact where there are interdependencies. The MAGICC model – a reduced climate model calibrated to simulate the output of full climate models – was used in WG III AR5 to estimate the climate implications of IAM emission pathways. At the same time, climate models rely on emissions data generated by the IAMs which in turn rely on underlying socio-economic assumptions. A continuing dialogue between modellers in WGs I and III, and in particular on the use of the MAGICC model, is therefore essential to work on these interdependencies.

A second potential link lies in the area of "geo-engineering" responses to climate change where there is the potential for overlap. The term "geo-engineering" covers a very wide range of potential climate change responses falling into two broad groups: those that involve the removal of GHGs from the atmosphere (GGR); and those that involve the management of solar radiation (SRM). While it has been argued that SRM approaches do not constitute "mitigation" of climate change, these potential responses do not fit readily into the IPCC WG structure. WG III has a potential role simply because they are potential "responses".

Different geo-engineering approaches cover a wide spectrum ranging from scientific concept (e.g. marine cloud brightening, space mirrors) through to more demonstrable technologies such as bioenergy with carbon capture and storage (BECCS) to which a cost of CO_2 abatement might be attributed. An option is to assess approaches closer to scientific concept in WG I and those that are closer to commercial application in WG III. However, both this principle and the detailed implementation of that principle need to be explored.

Working Group II

Many responses to climate change embody aspects of both mitigation and adaptation notably in relation to human settlements, including built environment and transport, land use management and water. For example, the restoration of degraded land may be an adaptation response but will also contribute to mitigation by storing carbon in soil. Article 4 of the Paris Agreement notes that "mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans can contribute to mitigation outcomes under this Article." There is some potential for WG II/III overlap in this area. However, the pragmatic solution may be to cover overlapping topics in both reports with cross-referencing as necessary.

Since both WGs II and III are concerned with climate responses, there are common concerns with human behaviour, institutions, governance, and policy frameworks. To the extent that mitigation and adaptation governance and institutions are distinct in an empirical and practical sense this does not pose a challenge. However, there are opportunities to consider common framings of these issues, particularly if AR6 pays greater attention to social science contributions to understanding. Approaches to making use of indigenous knowledge could also merit consideration.

The "shared socio-economic pathways" (SSPs) being jointly developed by a number of research communities could be part of a bridge-building exercise between WGs II and III.

Task Force on Inventories

Ambitious mitigation pathways that include GGR rely increasingly on responses in the AFOLU as well as the energy sector. AFOLU emissions and sinks are subject to greater uncertainties than energy sector emissions and the challenge of robust inventory approaches is tied up more intimately with the challenge of identifying and implementing "MRVable" (measurable, reportable and verifiable) mitigation responses. Furthermore, the TFI will refine its guidance on fugitive emissions from energy systems during AR6. At the very least, there is a need for WG III and the TFI to remain apprised of each other's work and cross-refer as necessary.

B.III.6 Interface with other AR6 Special Reports and activities

The scope for overlap between WG III AR6 and the three Special Reports is very considerable. This is inherent in the way that the Special Reports have been defined. The broad scope of two ("land" and "oceans and cryosphere") is based on geographical concepts, global warming 1.5°C is a based on a level of climate ambition and the three AR6 WG reports follow the physical science/impacts-adaptation-vulnerability/mitigation split which, as noted in Section 4, already provides scope for overlap. Certain topics, for example those falling under the "geo-engineering" umbrella could logically be covered under three (or perhaps more) reports. For example, BECCS, which played a big role in most ambitious climate mitigation scenarios assessed in AR5, could be covered in the "land" report because of the implied land use implications of large-scale biomass use, in the 1.5°C report because of its role in pathways emission and in the WG III AR6 report as a mitigation technology with wider sustainability consequences.

The conference on cities being planned by IPCC in lieu of a Special Report should provide valuable input for both WGs II and III.

If unnecessary overlap is to be avoided, the many points of intersection need to be systematically explored and solutions identified. Ideally, specific topics would be treated thoroughly in only one IPCC report with suitable cross-references in other reports where relevant. The treatment of ocean renewable energy provides an example. The decision was made to assess this topic alongside other energy sector mitigation options in the WG III AR6 report with a cross-reference in the "oceans and cryosphere" Special Report.

It would be worthwhile considering this at the Bureau level where it would be possible to take a comprehensive view across all report planned for the AR6 cycle. The preferred approach would be to provide a summary treatment in one report and cross-refer to the report which provides a comprehensive treatment. One other option, which builds on the observation that readers tend to dip into reports rather than read them end to end, is to provide comprehensive and nearly identical treatments in more than one report ("cut and paste" solution). This would, however, be difficult to implement in practice.
Under the preferred approach, it would be possible to develop guidelines for allocating topics, e.g.:

1. If a topic is urgent from a policymaker's perspective → Special Report
2. If the topic is relevant to more than one WG → Special Report
3. If new literature is emerging only slowly → main AR6 report
4. If the topic has been well-covered in previous reports → main AR6 report
5. Consider "adjacent" topics (as with ocean renewables and other renewable options) and place in the report covering related topics

In any case there may be advances in the literature between a Special Report and the main AR6 report which would need to be reported. However, the outcome that should be avoided is allowing important topics to "fall between the cracks".

Providing comprehensive treatments in two reports which are written from different perspectives, selectively assess different literature and open up the possibility of conflicting messages.

B.III.7 Approaches to communication

The aspirations concerning communication in Part A of this document are particularly pertinent for WG III whose past contributions have been demonstrably difficult to interpret for general audiences.

It is the ambition of the WG III Bureau to improve the communication of its contributions to the AR6 report and the Special Reports. The focus will be on the "communicability" of the relevant reports, including the underlying chapters but with a particular focus on the high profile Summaries for Policymakers (SPMs). This must be achieved without compromising the scientific integrity of the reports.

The first step will be to apply all of the lessons derived from the IPCC Expert Meeting on Communications held in February 2016. The elements that provide guidance on graphical presentation (e.g. not overloading figures with too much information) and language are particularly pertinent. A specific issue for WG III is the communication of uncertainty following the IPCC Guidelines, especially with regard to IAM scenario ensembles. This resulted in some particularly contorted language in AR5. Further attention will be given to improving the transparency of assumptions and approaches associated with scenarios and modelling. An Expert Meeting on *Mitigation, Sustainability and Stabilization Scenarios* organised by WG III in April 2017 will address, *inter alia*, this issue.

The main means of operationalizing the approach to communication will be the appointment, within the TSU, of a communications specialist whose primary task will be to work with the authors to improve graphical and written communication for the start of the writing process.

C. Cross-cutting Issues

Co-chairs of Working Groups have identified eight key themes that are cross-cutting across all Working Groups (1-5), or specific to Working Groups I and II (6) or II and III (7-8).

These themes have implications for the outline of each Working Group and may therefore motivate specific allocation of time during the scoping meeting to explore how best to cover them in the AR6 Working Group reports.

1. Scenarios and pathways (incl emission data, radiative forcing) I-II-III

There are close linkages and interdependencies between physical Earth system models and integrated assessment models (IAMs), which rely on underlying socio-economic assumptions. Emissions data from the IAMs and related radiative forcings are used for climate projections, while the reduced-complexity, simple climate models used by the IAMs are calibrated against the full Earth system models. Vulnerabilities, impacts, risks and adaptation options depend on both projected climate changes and socio-economic scenarios. The « shared socio-economic pathways » jointly developed by a number of research communities are part of a bridge-building exercise across all Working Groups.

2. Risk assessment I-II-III

Risk assessment provides a common framework, going beyond cost-benefit analysis, for addressing responses to climate change. Due to the interactions of climate change as well as environmental and human factors involved in exposure, vulnerability and adaptive capacity, a harmonised approach across Working Groups is desirable. More specifically, this theme covers the assessment of risks associated with progressive climate change, i.e. caused by slow onset events such as ocean acidification or sea level rise, as well as fast onset events such as extreme weather and climate events (including compound and cascading events). This theme also covers the risks of abrupt and/or irreversible changes and risks of crossing thresholds in ecosystems or socio-ecological systems. Risks can be reduced by implementing adaptation and/or mitigation options. At the same time, some mitigation options, and solar radiation management, carry their own risks. Assessments of risk perception and the social acceptability of such options, their economic costs and impacts on equity are carried out across Working Groups.

3. Solar radiation management and greenhouse gas removal I-II-III- TFI

Since the AR5, new research on solar radiation management (SRM) and greenhouse gas removal (GGR) has emerged. Some research has elaborated scientific concepts, while other approaches are at, or are close to, commercial implementation. These potential response options do not fit readily into the IPCC Working Group structure. Specifically, it has been argued that solar radiation approaches do not constitute “mitigation” of climate change. These approaches therefore need to be assessed across all Working Groups (physical science basis; impacts, adaptation and vulnerability; and mitigation of climate change). While they have the potential to mitigate some impacts of climate change on ecosystems and human societies, they may entail unintended side effects, and SRM without reduced CO_2 emissions would leave ocean acidification unabated. Ambitious mitigation pathways that include GGR rely increasingly on responses in the AFOLU as well as the energy sector. AFOLU emissions and sinks are subject to greater uncertainty than energy sector emissions, and the challenge of robust inventory approaches is tied up more intimately with the challenge of identifying and implementing measurable, reportable and verifiable mitigation responses. AR6 is expected to provide an assessment of how SRM and GGR approaches may mitigate the impacts of climate change including ocean acidification on ecosystems and human societies.

4. Air quality and short-lived climate pollutants I-II-III

Emissions of short-lived climate pollutants (e.g. methane, carbon monoxide, hydrofluorocarbons and black carbon which is produced by incomplete combustion of fossil fuels and biomass) have a warming influence on climate through their radiative forcing. Some short-lived pollutants act as precursors of tropospheric ozone, which also has a warming effect. On the other hand, sulphate aerosols and their interactions with clouds have a cooling effect on climate. Black carbon is always emitted with co-pollutants (organic carbon and sulphate aerosols); these small particles cause poor health and premature deaths. Ground-level ozone also has detrimental impacts on human health, plants and crop yields. The AR5 stressed that projections of air quality are driven primarily by emissions, and that the response of air quality to climate-driven changes was more uncertain than the response to emission-driven changes. Regional chemistry and local emission feedbacks may be triggered by higher surface air temperatures in polluted regions (e.g. cities), and increase peak levels of ozone and micro-particles. The AR6 needs to further assess our understanding of the influence of short-lived drivers on climate change and air quality, and how improved air quality resulting from adaptation and mitigation options provides co-benefits for human health, well-being and longevity as well as crop yields, ecosystems and biodiversity.

5. Water and carbon in a changing climate I-II-III

Over land masses, changes in water availability, terrestrial photosynthesis, vegetation and greenhouse gas fluxes between the land surface and the atmosphere are closely related in a changing climate. They are also affected by water and land management response options. Changing oceans, including ocean acidification, affect marine ecosystems, and in turn the capacity of ocean carbon sinks. This theme aims to identify the interplays between Working Group I and Working Group II reports for water, carbon, terrestrial and marine ecosystems, and facilitate the design of report outlines to strengthen the coherency of the assessments. It also covers Working Group III concerns with the impacts of and constraints on land-based mitigation options related to water availability and competition for water.

6. Regional climate change and impacts, and options for a common atlas I-II

An enhanced focus on regions is timely in AR6 to reflect science developments that were not available for AR5, such as the production of regional climate and impact modelling at a high spatial resolution, and improved detection and attribution at regional scale. These efforts are providing new highly policy-relevant information for AR6. Building on relevant information from Working Group I (regional climate including hydrological aspects, coastal sea level, extreme events, cf. CORDEX), Working Group II will assess impacts, risks, vulnerability, adaptation options at the level of regions. Each region will include coasts and coastal ocean (Exclusive Economic Zones). Institutional challenges in the regions need to be considered, as well as their different governance backgrounds. It is envisioned that Working Group I and II authors may be able to jointly produce regional maps of observed as well as projected climate changes and impacts.

7. Integration of adaptation and mitigation responses II-III

In AR6, Working Group II and Working Group III will assess the knowledge base addressing synergies, trade-offs and the integration of mitigation and adaptation responses to climate change as well as their integration with actions addressing sustainable development. Article 4 of the Paris Agreement notes that “mitigation co-benefits resulting from Parties’ adaptation actions and/or economic diversification plans can contribute to mitigation outcomes under this Article” while Article 7 stresses that “the current need for adaptation is significant and that greater levels of mitigation can reduce the need for additional adaptation efforts”. Responses to climate change therefore embody aspects of both mitigation and adaptation in relation to, for example, human settlements, land use management and water. For example, the restoration of degraded land may be an adaptation response but will also contribute to mitigation by storing carbon in soil. This example would draw also on Working Group I knowledge on soil processes and soil carbon storage. Working Groups II

and III will need to develop common approaches to assessment and consider how specific topics might be allocated between the Working Group II and III reports, as well as the Special Reports currently under development.

8. Decision making II-III

Climate change mitigation and adaptation responses entail risks; decisions about their adoption are made under conditions of uncertainty. Climate change decisions are complex since the pros and cons of alternatives need to be evaluated against multiple criteria and the outcomes may be realized in the distant future. Besides, climate change decisions involve numerous decision makers with diverse objectives and levels of understanding of the science and the complexity of analytical tools. There is a common need across Working Groups II and III need to address institutional aspects of decision -making across all scales. Decision making methods and tools can support transparent and informed choices from among alternatives by structuring decision problems, identifying alternatives, quantifying uncertainties and risks and valuing outcomes. An integrated and interdisciplinary approach that addresses all dimensions and scales of decision making is essential for generating a comprehensive, policy relevant narrative across Working Groups II and III.