The twelfth meeting of the research dialogue, 2020

24 – 25 November 2020

Summary report by the Chair of the SBSTA

05 May 2020

Overview

The Paris Agreement provides the framework for action on climate change. As Parties submit updated or revised nationally determined contributions (NDCs), governments must consider how to move to a global net-zero greenhouse gas (GHG) emissions society (Article 4.1) whilst enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change (Article 7.1) in the context of the long-term temperature goal (Article 2). This action must be based on the best available science and have clear short-term goals in order to reach 2050 ambitions.

The twelfth meeting of the SBSTA research dialogue focussed on **science for global net-zero** to provide updates on science and enhancing understanding to accelerate mitigation and adaptation. The meeting explored the latest research and research needs on both moving towards net zero global anthropogenic carbon dioxide emissions in the context of Article 4.1 (hereafter referred to as global net-zero) and some of the factors needed to mitigate emissions and build resilience to the impacts and risks of climate change in this context.

This summary report provides an overview of the plenary presentations and discussions as well as the posters from the two days of the dialogue. Overarching messages from the plenary discussions are also provided.

Table of Contents

Page

Overarching messages **3**

I. Introduction **6**

II. Summary of plenary presentations and discussions and posters on Theme 1: Updates on advancements in research and modelling **7**

A. Proceedings 7

B. Poster Session 27

III. Summary of presentations and discussions at the World Adaptation Science Programme special event **30**

IV. Summary of plenary presentations and discussions and posters on Theme 2: Factors for enhancing understanding to accelerate adaptation and mitigation **35**

A. Proceedings 35

B. Poster Session 522

Overarching messages

Updates on advancements in research and modelling

Updates from the World Climate Research Programme

- Research shows that the Earth climate system has already entered a new phase with associated impacts and risks that have strong regional differences
- Designed through partnerships and community consultation, the WCRP lighthouse activities will support global, regional and local science needs, build capacity and create new homes for delivery of the latest data and information

Updates from the World Adaptation Science Programme

- The WASP provides policy-relevant scientific research on adaptation with an emphasis on vulnerable developing countries
- The WASP recognizes that adaptation research must have a holistic forward-looking approach to engage stakeholders, address knowledge and research needs, engage policy makers to support action agendas and funders to scale-up action
- Three Science for Adaptation Policy Briefs have been produced on: Adaptation decision-support tools and platforms; Transboundary climate risk and adaptation; and High-end climate change and adaptation

Updates from modelling studies on COVID-19 implications, net-zero scenarios, and bridging the gap

- The investment needed in the energy sector to shift to a 1.5˚C or 2˚C compatible pathway is small compared to the current investment in COVID-19 stimulus packages
- Emission scenarios with limited or no use of negative emissions show higher costs in the short-term but greater long-term economic benefits than scenarios that include negative emissions
- The transfer of good practices could be significantly helpful in bridging the emissions gap

Opportunities, risks and benefits of CDR to reach net zero

- Carbon dioxide removal (CDR) is absolutely necessary for reaching net-zero CO_2 emissions
- Reliance on CDR grows with every tonne of CO_2 emitted
- All CDR options have limits and potential for negative side-effects that grow with the scale of implementation
- Choices around how much CDR, when, and how, need to become core parts of climate policy to reduce over-reliance and forced trade-offs
- Net-zero is not the end goal of climate policy
- Investments in R&D and pilot projects as well as appropriate institutional and governance frameworks are needed to match the required reliance on CDR

Scientific and societal assessment of potential ocean interventions for climate change mitigation

- A number of ocean interventions have been proposed for climate change mitigation, including CDR, but there is currently insufficient knowledge on these interventions for evidence-based decision making
- Frameworks are needed for research on ocean interventions for climate change mitigation and for coordinated reporting of approaches

- Current knowledge of the ocean carbon system and its biological component are insufficient to assess consequences of CDR – a holistic coordinated response is proposed by IOC-R
- Governance should be an important element of future assessment and research of marine CDR

Updates on biodiversity loss and transitions needed for a sustainable future

- Biodiversity, and the services it provides, are in a serious rate of decline
- It is not too late to slow, halt and eventually reverse current trends in the decline of biodiversity and the actions needed are fully consistent with the Paris Agreement
- Substantial changes, innovations, and a portfolio of actions implemented on a short timescale and involving a wide range of actors across all scales and sectors is needed
- Increased collaboration between UNFCCC and the CBD, and IPCC and IPBES, is needed

Factors for enhancing understanding to accelerate adaptation and mitigation

Understanding options and opportunities to support reaching net zero with renewable energy

- Renewable energy options play a critical role in achieving net zero
- Achieving net-zero, for a 2˚C pathway, would require an additional investment of USD 20 trillion by 2050
- For power and personal transport – solutions are known and available. However, for 7 challenging industry and transport sectors (iron and steel, chemicals and petrochemicals, cement and lime, aluminium, road freight, aviation, shipping) – more information is needed to accelerate mitigation
- Priority actions to address knowledge gaps and enable mitigation across the 7 challenging industry and transport sectors have been identified

Research needs on consumption and behaviour for net zero

- More social science research is needed on sustainable consumption to examine the diverse ways people aspire to live well whilst living within planetary limits in the context of reaching the goals of the Paris Agreement and other international agreements
- An increase in social science research on consumption and behaviour must be combined and coupled with scholarly works on sustainable living produced by local peoples, indigenous peoples, and those from the global South
- A transdisciplinary research approach is needed to identify how demand can be managed to reduce consumption

Understanding research on climate finance for net zero

- Misallocation of capital is limiting the financial sector's potential to be an enabler of the net zero transition
- Stranded assets and resources are expected to become a major economic burden for states and, therefore, also for taxpayers in the net zero transition
- A higher level of transparency and synergised approaches are needed for net zero transition
- Understanding debt sustainability is vital for a just net zero transition
- Research on climate change economics and considerations of traditional debt levels must consider new perspectives on and requirements of debt sustainability

Understanding contextual climate action needs at regional level in the Asia Pacific

- APN continues to support information exchange and capacity building in the Asia Pacific region to enhance understanding of science to support adaptation and mitigation
- Future activities should focus on generation of more products that are evidence-based and structured around frameworks to make them easily useable to inform policy

Welcoming complexity in adaptation research, policy and action

- Adaptation is complex and 'messy' and requires understanding of technical and human social processes exploring new ways of doing research, forming partnerships, engaging with stakeholders to achieve a meaningful change
- The context of adaptation decision making informs what counts and does not count – and more emphasis must be given in research and decision making on social factors such as gender, equity, institutional context and the nature of transformation
- As adaptation is complex and messy, so is adaptation research and research capacity building– it must be multidisciplinary and inclusive to make positive impacts on human lives

Understanding how to accelerate action on climate change: Engaging with the practical, political, and personal spheres of transformation

- Accelerating action on climate change needs strategies and the strategies are messy and more complex than building back better
- The three spheres of transformation framework can be used to understand and activate transformation for sustainability and people and meet the Paris Agreement goals
- Increased understanding is needed in order for society to design for change and shift systems and structures that are not aligned or working with the goals that we have set out for ourselves such as under the Paris Agreement

I. Introduction

1. The twelfth meeting of the Subsidiary Body for Scientific and Technological Advice (SBSTA) Research Dialogue[1] was held during the virtual UNFCCC Climate Change Dialogues[2], 23 November – 4 December 2020.

2. The foundation for the annual meetings of the research dialogue was given by the Conference of the Parties (COP) decision 9/CP.11 and further focus provided by conclusions of the SBSTA and COP decision 16/CP.17.[3] The meetings provide the opportunity to explore topics relevant to the Convention[4] and the Paris Agreement.[5] It enables engagement between a wide range of experts from the research community, Parties and non-Party stakeholders to support the implementation of the Convention and the Paris Agreement.

3. At its fiftieth session, the SBSTA invited Parties to submit their views on possible topics and considerations for the research dialogue to be held in conjunction with SBSTA 52 (June 2020) and beyond. Due to the COVID-19 pandemic, SBSTA 52 was postponed to 2021 and did not take place in June 2020. However, to advance the work of SBSTA, the 12th meeting of the research dialogue took place in November as part of the Climate Change Dialogues 2020 organized by the SB Chairs in collaboration with the COP25 and COP26 Presidencies.

4. The themes and topics for the meeting were guided by Parties' submissions,[6] and in consideration of the mandates and the wider context of ongoing work under the UNFCCC as well as the three recent IPCC reports (SR1.5, SRCCL, SROCC).

5. The year 2020 was the year in which Parties' were due to provide updated or revised nationally determined contributions (NDCs). Against this backdrop, the research dialogue presented the latest science for Parties to consider how to move to a global net-zero greenhouse gas (GHG) emissions society (Article 4.1 of the Paris Agreement) whilst also increasing resilience to the unavoidable impacts of climate change (Article 7.1) in the context of the long-term temperature goal (Article 2).

6. The twelfth meting explored the scientific research and understanding of moving towards net zero global anthropogenic carbon dioxide emissions (hereafter referred to as global net-zero) and building resilience to the unavoidable impacts and risks of climate change in this context. The IPCC[7] defines CDR as anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products.

7. The dialogue addressed two themes over two days:

- Theme 1 / Day 1: Updates on advancements in research and modelling.
- Theme 2 / Day 2: Factors for enhancing understanding to accelerate adaptation and mitigation.

8. Each day consisted of a 2-hour dialogue with supporting posters. On both days 2 1-hour poster Q&A sessions were held to enable participants to ask questions of the poster presenters. In addition, a special event took place on Day 1 in collaboration with the World Adaptation Science Programme to share advancements on adaptation research under theme 1.

9. The meeting was chaired by the SBSTA chair Mr. Mr. Tosi Mpanu Mpanu, Democratic Republic of the Congo.

10. I prepared an information note in advance of the event to provide an overview of the themes addressed as well as guiding questions to help focus presentations and discussions.

[1] See https://unfccc.int/topics/science/events-meetings/research-dialogue/twelfth-meeting-of-the-research-dialogue
[2] See https://unfccc.int/cd2020
[3] An overview of the mandates founding and guiding the research dialogue are available here: https://unfccc.int/topics/science/resources/research-background
[4] Available at https://unfccc.int/resource/docs/convkp/conveng.pdf
[5] Available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[6] Submissions were provided by Belize on behalf of the Alliance of Small Island States (AOSIS), Bhutan on behalf of the Least Developed Countries Group, Croatia and the European Commission on behalf of the European Union and its Member States, the Republic of Fiji, the Republic of Gabon on behalf of the African Group, and Japan.
[7] See https://www.ipcc.ch/sr15/

11. The guiding questions were:

- With regards to the topic presented, what is the latest scientific research and information available, and its implications for policy makers, to accelerate the sustainable way forwards post-COVID 19 towards resilience and a global net-zero society?
- What are some of the research disciplines and/or research capacity building options that must be considered and better understood with regards to understanding how to accelerate action on climate change and sustainable development?
- What are the opportunities, gaps and needs in research knowledge, access to research, capacity building for research, as well as in support to unlock understanding?

12. This report provides a summary of the plenary presentations and discussions, as well as a summary of the posters.

- Section II summarises the presentations, posters and discussion on Theme 1.
- Section III summarises the presentations and discussion from the World Adaptation Science Programme special event.
- Section IV presents the presentations, posters and discussion on Theme 2.
- Twelve individual presentation were given during the dialogue, with a further three during the WASP special event. The poster session of the dialogue consisted of 15 posters.

13. I encourage Parties to consider the information in this summary report as part of the basis for negotiations on research and systematic observation at upcoming SBSTA sessions.

II. Summary of plenary presentations and discussions and posters on Theme 1: Updates on advancements in research and modelling

14. Presenters for Theme 1 were Mr. Mike Sparrow, Head, WCRP Secretariat; Ms. Minpeng Chen and Mr. Anand Patwardhan, Co-Chairs, WASP; Mr. Bas van Ruijven, Research Group Leader, IIASA; Mr. Andy Reisinger, Principal Scientist, Climate Change, Ministry for the Environment, New Zealand; Mr. Chris Vivian, GESAMP WG 41; Mr. Hesiquio Benitez Diaz, SBSTTA Chair, UN Convention on Biological Diversity.

A. Proceedings

1. Updates from the World Climate Research Programme

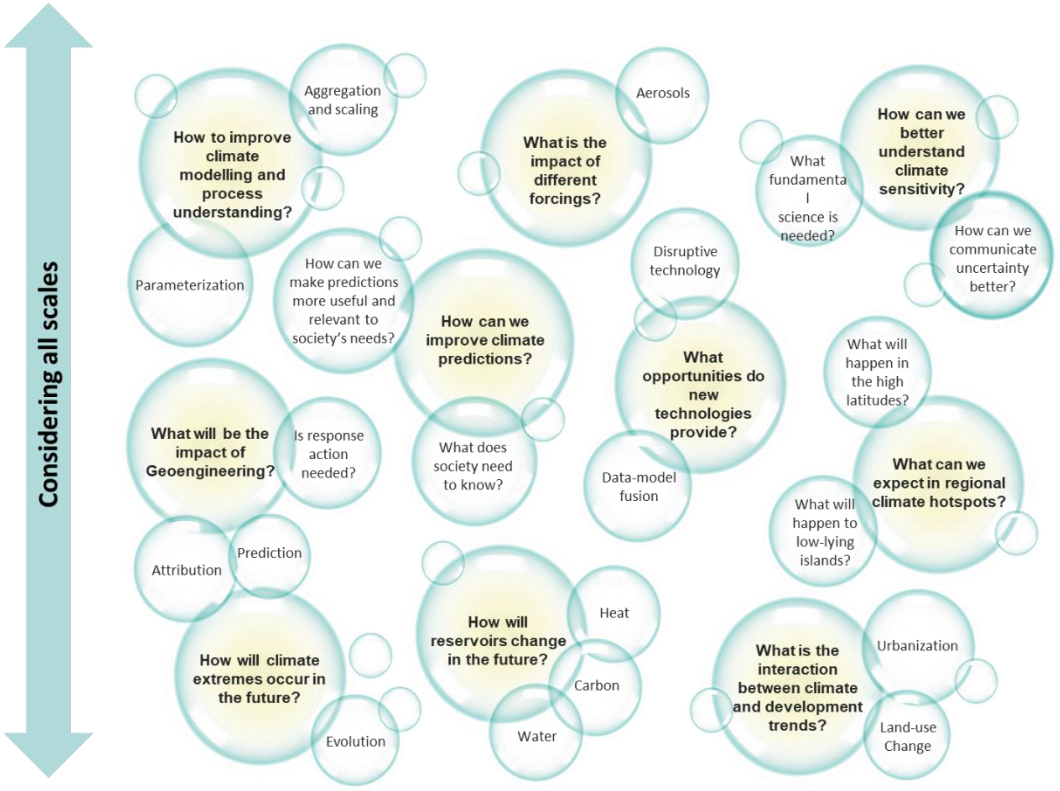
15. Mr. Mike Sparrow opened the presentations with an update from the World Climate Research Programme[8] on its new plan and recent relevant research results. The WCRP strategic plan, 2019 to 2028, consists of four overarching scientific objectives:

- The fundamental understanding of the climate system;
- Short-term annual-decadal predictions;
- Long-term projections of the responses of the climate system;
- Bridging climate science and society by linking science to services and providing scientific advice to policymakers. This links the WCRP to the UNFCCC, the Sendai Framework, and the SDGs.

16. The WCRP are partnering across the research and systematic observation communities to address a large range of high-level climate science questions across all scales as part of the implementation of the plan (figure 1).

[8] See https://www.wcrp-climate.org/

Figure 1
High level science questions being addressed by WCRP strategic plan 2019 to 2028



Source: Slide 3 of Mr. Sparrow's presentation

17. Implementation of the strategic plan can only be achieved through partnership and with funding. WCRP activities focus on the science to society value chain and current examples include:

a). The WMO Annual-to-Decadal Outlook 2020-2024,[9] originating from the WCRP grand challenge on near-term climate prediction, predicts a 20% chance that one of the next five years will be at least 1.5˚ C warmer than pre-industrial levels, with increasing likelihood of the exceedance of this temperature limit in the near future;

b). The FOCUS Africa[10] project, coordinated by WMO, aims to strengthen services for the Southern Africa Development Community[11] to address food security, energy, infrastructure, and water in a changing climate;

c). Input to the UN Ocean Decade on Science for Sustainable Development,[12] coordinated from the Climate and Ocean: Variability, Predictability and Change project (CLIVAR)[13] and the WCRP Grand Challenge on Regional Sea-Level Change and Coastal Impacts,[14] will consider societal needs, the ocean science that is required, and the services and outputs that will be created over the Decade.

18. Climate change decision making requires risk assessment and risk management. This requires a meaningful measure of both the likelihood and impact of specific events over different time scales.

19. The new WCRP focus highlighted in the strategic plan requires changes in structure and working methodology to respond to the need for robust and useful **regional and local** climate information on risk over different timescales. Climate change decision making requires risk assessment and risk management.

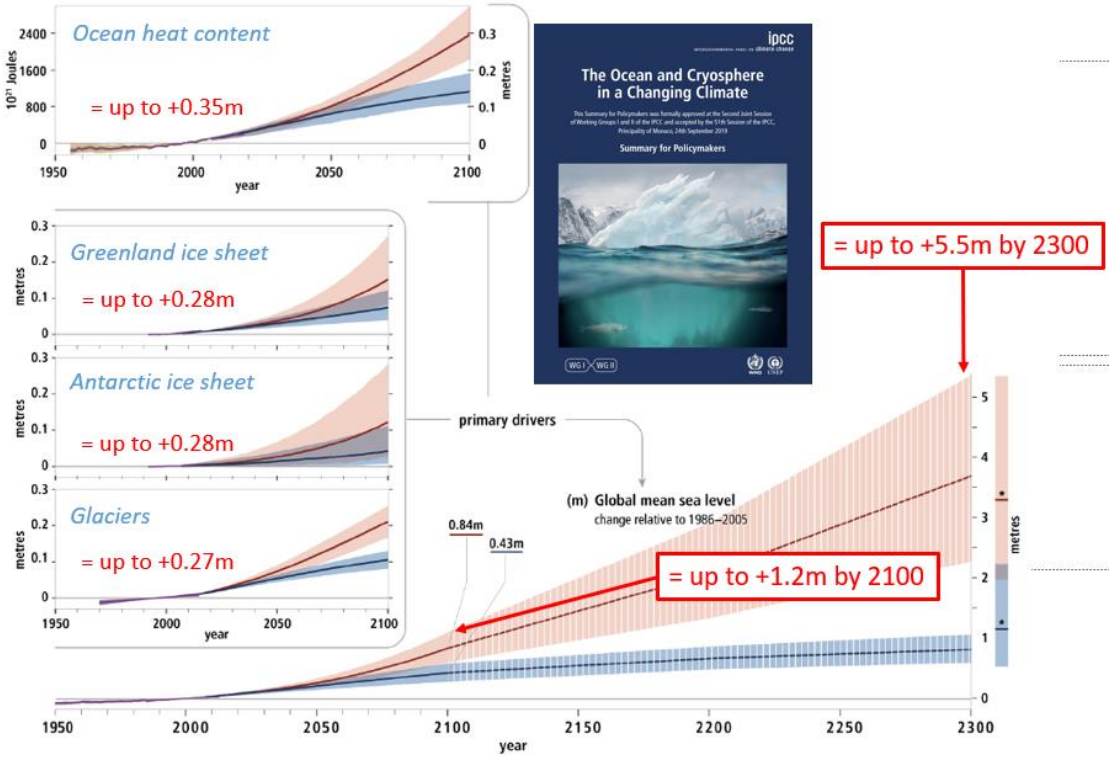
[9] See https://hadleyserver.metoffice.gov.uk/wmolc/
[10] See https://public.wmo.int/en/projects/full-value-chain-optimised-climate-user-centric-services-southern-africa-focus-africa
[11] See https://www.sadc.int/
[12] See https://www.oceandecade.org/
[13] See https://www.clivar.org/
[14] See https://www.wcrp-climate.org/gc-sea-level

This requires a meaningful measure of both the likelihood and impact of specific events over different time scales.

20. The Coordinated Regional Climate Downscaling Experiment[15] (CORDEX) continues to provide regionally downscaled information for 14 domains. WCRP aim to provide suitable cooperation platforms for different regions but also for improved global/cross-regional cooperation. For example, CORDEX is now incorporating interactive glaciers into high-resolution regional models to improve representation of surface mass balance and hydrological processes. CORDEX and the WCRP take into full consideration the different strengths and limitations of different regions such as internet accessibility, bandwidth, technical limitations, and restrictions within countries or regions. Understanding this is essential to provide information in a format that is useful to all countries.

21. Although the IPCC Special Report on the Ocean and Cryosphere[16] presented the latest globally aggregated knowledge on factors affecting sea level rise, uncertainties remain such as the fate of the Antarctic ice sheet and marine-based ice sheets (figure 2). These ice sheets sit on the bedrock and are vulnerable to the relatively warmer seawater flowing beneath them. The WCRP Climate and Cryosphere[17] (CliC) project and the Ice Sheet Model Intercomparison Project[18] (ISMIP) for CMIP6 are further researching these uncertainties.

Figure 2
Latest IPCC "likely" (66%) global sea-level projections – SROCC



Source: Slide 8 of Mr. Sparrow's presentation; IPCC. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. (2019)

[15] See https://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/cmip6-endorsed-mips-article/1052-modelling-cmip6/-cordex
[16] See https://www.ipcc.ch/srocc/
[17] See https://www.climate-cryosphere.org/
[18] See https://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/cmip6-endorsed-mips-article/1049-modelling-cmip6-ismip

Research shows that the Earth climate system has already entered a new phase with associated impacts and risks that have strong regional differences

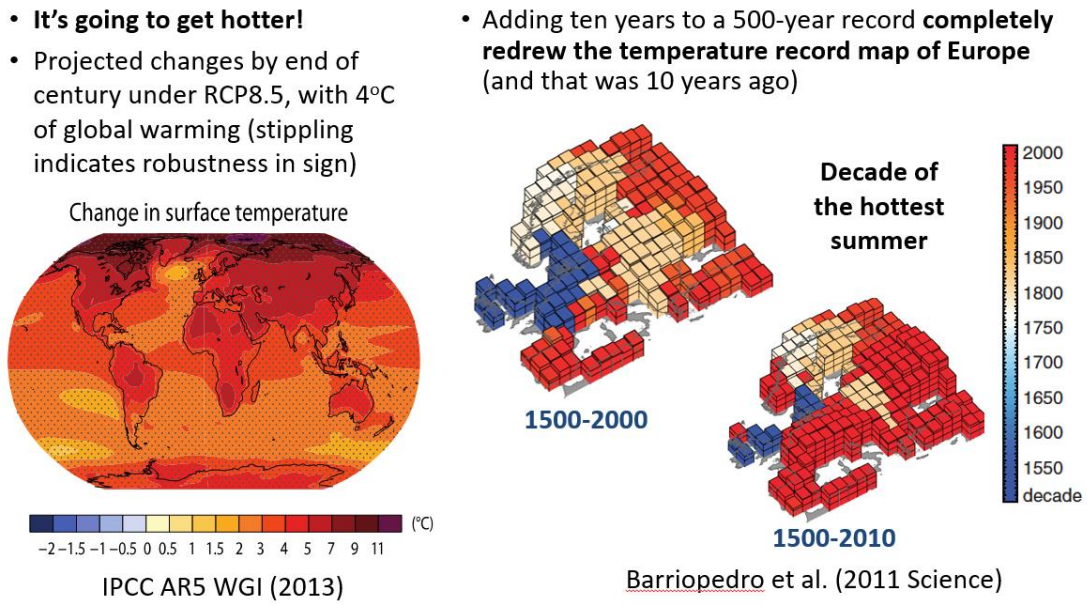
22. WCRP research on impacts and risks of warming show strong regional differences, with greater temperature rise over the poles and landmasses. Historical data compared to data from the last 10 or 20 years reveals that we are entering a new Earth system 'mode':

a). The recent heat waves in Europe are indicative of this new system mode and have redrawn the European temperature map (figure 3).

b). In South Africa, research shows that droughts will increase in intensity. In a 1.5˚ C and 2˚ C warmer world, changes in rainfall may be minor, but extreme high temperatures are far more likely to occur. Under a 1.5˚C world there is a 74% chance of summers matching those of the conditions of the 1991/92 drought, in a 2˚C world the chance is almost 100-percent (*Figure 4*).

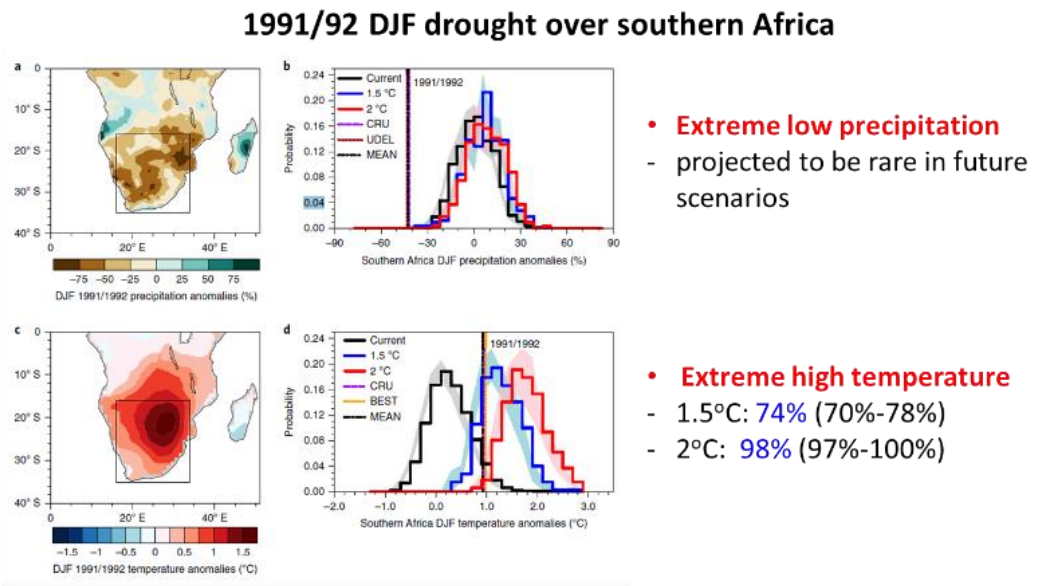
c). Research on extreme precipitation in monsoon regions, such as southern Africa, southern Asia and eastern Asia shows that these regions will be greatly affected by the half degree of warming difference between 1.5˚ and 2˚ C, increasing exposure by approximately 20 to 40%. Reducing global warming from 2˚ to 1.5˚ C would robustly reduce extreme rainfall events in these monsoon regions.

Figure 3
Projected and observed changes in surface temperature globally and in Europe



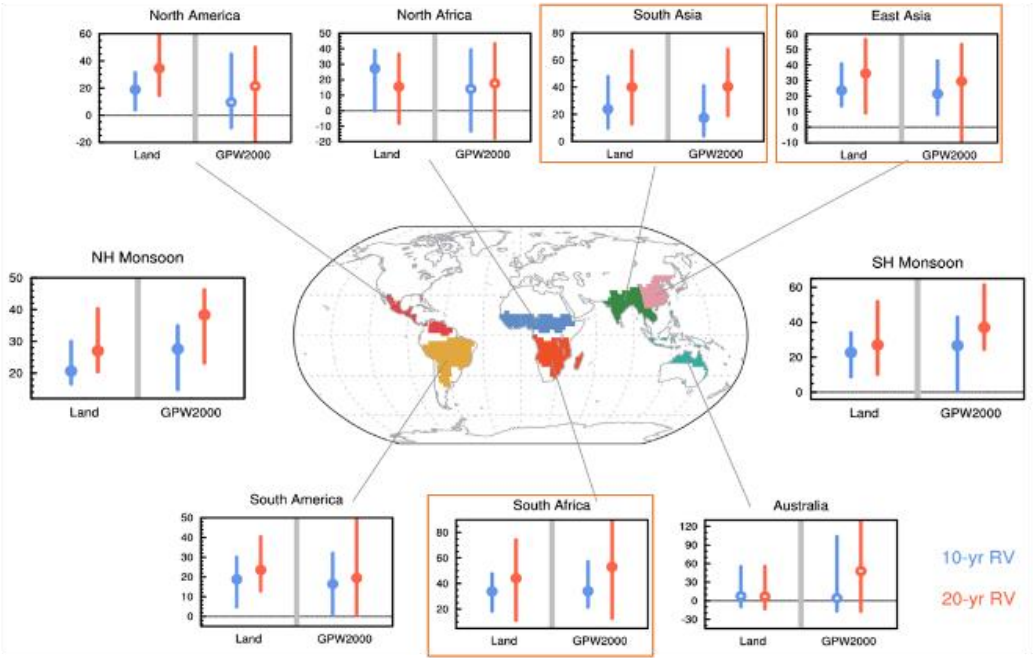
Projected global changes in surface temperature by 2100 (left), and the historical and modern European heatmaps (right). Source: Slide 11 of Dr. Sparrow's presentation. Barriopedro, D. et al. The Hot Summer of 2010: Redrawing the Temperature Record Map of Europe. Science (2011). DOI: 10.1126/science.1201224

Figure 4
Drought rish in Southern Africa increases from 1.5˚ C to 2˚ C global warming



Regardless of the insignificant precipitation change projected, excessive warming alone might increase the probability of similar droughts occurring in a warmer world. Source: Slide 13 of Dr Sparrow's presentation; Nangombe S., Tianjun Z., Wenxia Z., et al. Record-breaking climate extremes in Africa under stabilized 1.5° C and 2° C global warming scenarios. Nature Climate Change (2018). https://doi.org/10.1038/s41558-018-0145-6

Figure 5
Extreme precipitation risks in global monsoon regions from 1.5° C to 2° C global warming

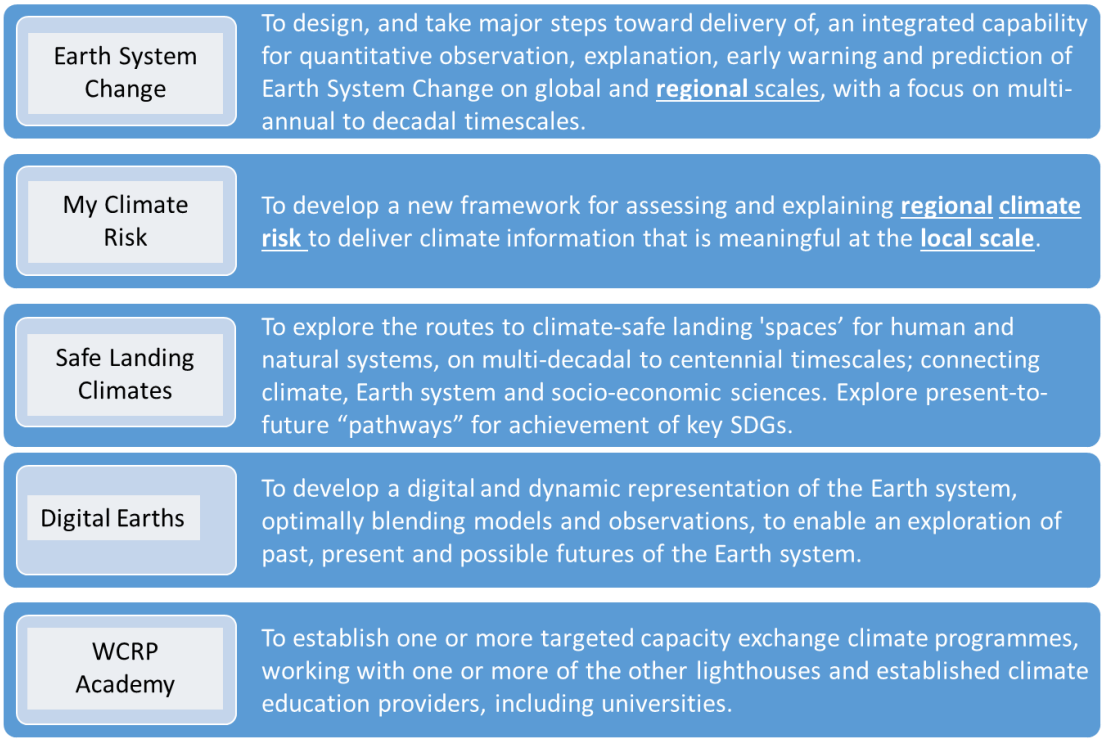


Regional hotspots: South African, South Asian, and East Asian monsoon regions will be affected most by the 0.5°C additional warming. Source: Slide 14 of Dr Sparrow's presentation; Zhang W., T. Zhou, L. Zou, L. Zhang, X. Chen. Reduced exposure to extreme precipitation by 0.5°C less warming for global land monsoon regions. Nature Communications (2018). https://doi.org/10.1038/s41467-018-05633-3

Designed through partnerships and community consultation, the WCRP lighthouse activities will support global, regional and local science needs, build capacity and create new homes for delivery of the latest data and information

23. WCRP have proposed Lighthouse activities[19] that will be implemented as part of the WCRP strategy (figure 6). These require and are designed through partnerships and community consultation and have global, regional, and local foci. In the coming months WCRP will be consulting with the global community on its strategy, new activities and proposed new structure. It is working to create new "homes" for modelling and observations and for regional climate information for society.

Figure 6
WCRP Lighthouse activities



Source: Slide 15 of Mr. Sparrow's presentation

2. Updates from the World Adaptation Science Programme

24. Ms. Minpeng Chen and Mr. Anand Patwardhan presented on the activities of the World Adaptation Science Programme[20] (WASP), which has its origins in the former UNEP Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA). The WASP focuses on policy relevant scientific research with an emphasis on vulnerable developing countries. The three main components of the programme are filling current research gaps, future research gaps, and providing policy relevant guidance.

The WASP provides policy-relevant scientific research on adaptation with an emphasis on vulnerable developing countries

25. WASP is actively responsive to emerging global contexts for research and action including:

a). New reality of a pandemic world - connecting COVID-19 response and recovery to longer-term adaptation & resilience building;

b). Increasingly visible impacts of climate change – and the urgency for scaling and accelerating actions for adaptation and resilience;

[19] See https://www.wcrp-climate.org/wcrp-ip-la
[20] See https://www.unenvironment.org/explore-topics/climate-change/what-we-do/climate-adaptation/world-adaptation-science-programme

c). New technologies reshaping lives, livelihoods and creating new opportunities – and building foresight and understanding of new technologies: AI, blockchain, regenerative approaches;

d). Need to rethink research, action and research – action linkages – with a focus on action-oriented, user-centered research;

e). Learning-by-doing and learning-while-doing;

f). Tightening research – implementation loops – to intervene at scale, rather than scaling from pilots.

26. In order to address these emerging global contexts, WASP undertakes 3 core and 2 partner activities (figure 7), which include:

Core activities

d). Adaptation Futures conference series- the 2020 conference was postponed to 2021. It will be themed around Knowledge for Action and aims to produce an outcome document to feed into COP 26;[21]

e). Science for Adaptation Policy Briefs[22], (see section III);

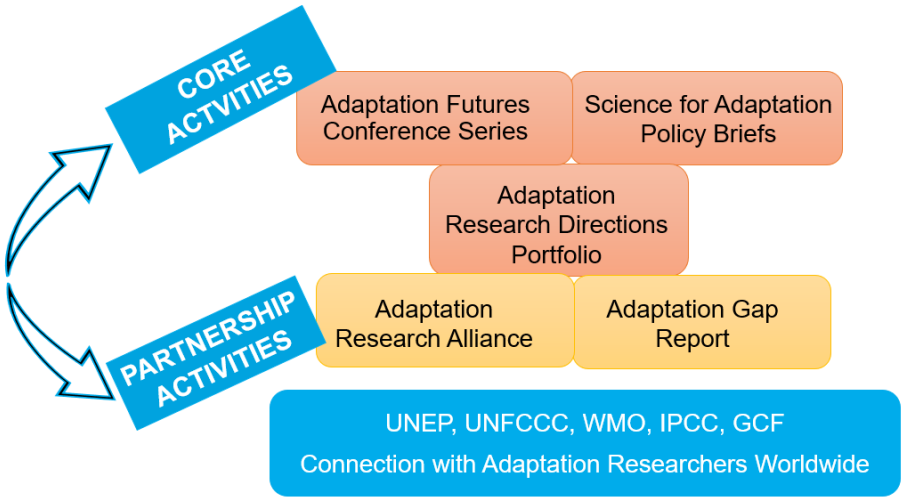
f). Adaptation Research Directions Portfolio considering the range of research already conducted[23] and the emerging global contexts above;

Partner activities

g). Adaptation Research Alliance a new initiative led by the UK as part of the COP 26 Adaptation and Resilience campaign, which aims to scale-up investment in action-oriented, user-centric research by creating a coalition across the research and funding communities;[24]

h). Adaptation Gap Report, in 2020 the Adaptation Gap Report focussed on planning, financing, and implementation. The rotating thematic deep-dive in this report was on nature-based solutions – a key interface area between adaptation and mitigation.[25]

Figure 7
WASP Core and Partnership Activities



Source: Slide 4 of Ms. Chen's presentation

[21] See http://adaptationfutures2020.in/
[22] See Section III
[23] See Callaghan, M.W., Minx, J.C. & Forster, P.M. A topography of climate change research. Nature Climate Change. (2020). https://doi.org/10.1038/s41558-019-0684-5
[24] See https://southsouthnorth.org/portfolio_page/adaptation-research-alliance/
[25] See https://www.unenvironment.org/resources/adaptation-gap-report-2020

The WASP recognizes that adaptation research must have a holistic forward-looking approach to engage stakeholders, address knowledge and research needs, engage policy makers to support action agendas and funders to scale-up action

27. In conclusion, Dr Patwardhan emphasised that adaptation is now a domain of practice as well as of research. WASP continues to build its collaborative activities and welcomes inputs from Parties and other stakeholders in terms of knowledge and research needs, as well supporting the action agenda and UNFCCC process through engagement with the IPCC, GCF and other complementary initiatives.

28. Moving forward, WASP seeks to continue to strengthen its contributions to policy and practice going forward. It envisions to better connect the Adaptation Futures conferences, Adaptation Gap Report, and Science briefs. Rather than a one-time event and list of 'priorities', the identification of research directions and opportunities will be an ongoing process, learning from and feeding into the overall workplan. Bringing together diverse funders and creating new funding platforms plays a critical role in advancing, scaling-up, and addressing knowledge gaps in adaptation.

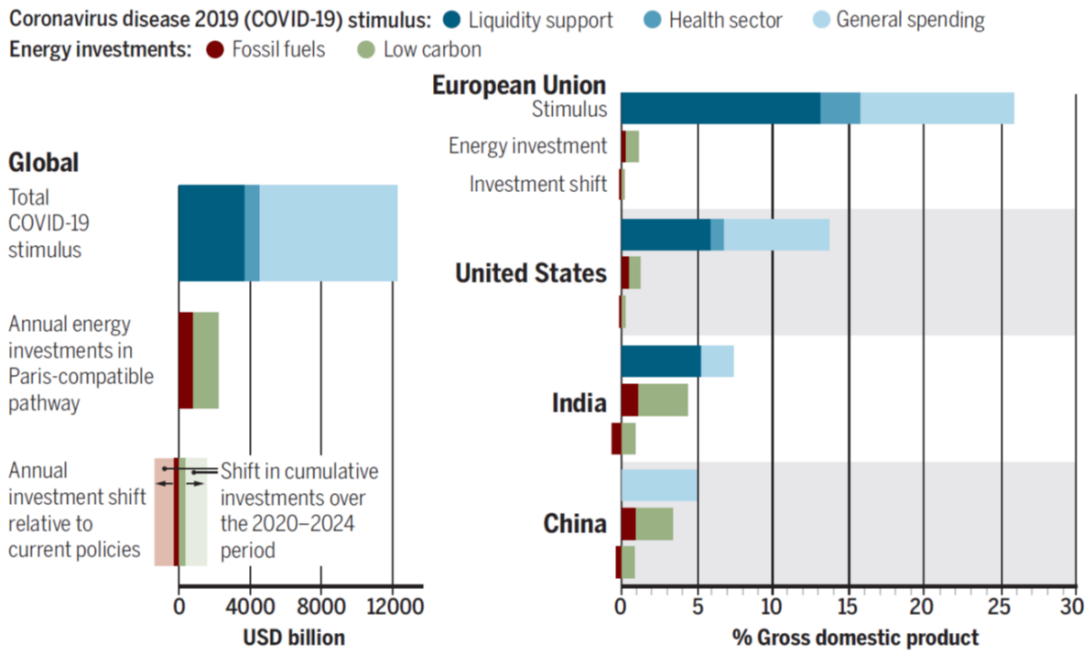
3. Updates from modelling studies on COVID-19 implications, net-zero scenarios, and bridging the gap

29. Mr. Bas van Ruijven presented updates from the Integrated Assessment Modelling Consortium on COVID-19 implications for net-zero scenarios and bridging the emissions gap in 2030.

The investment needed in the energy sector to shift to a 1.5˚C or 2˚C compatible pathway is small compared to the current investment in COVID-19 stimulus packages

30. Comparing COVID-19 stimulus packages to investment in energy systems for low carbon scenarios, total COVID-19 stimulus packages amount to about USD 12 trillion globally, dwarfing clean energy investment (figure 8). In the EU and the United States, the investment as a percentage of GDP required in the energy sector to achieve the 1.5˚ or 2˚ C targets is far less than investment in COVID-19 stimulus. In countries with smaller recovery packages than some western countries and higher investment needs in the energy sector, the investment as percentage of GDP in Paris-compatible energy pathways is higher and the difference between this percentage and that invested in COVID-19 stimulus packages is lower. In conclusion, the investment needed in the energy sector to shift to a 1.5˚ or 2˚ C compatible pathway is small compared to the current investment in COVID-19 stimulus packages.

Figure 8
COVID-19 investments compared with energy investments by region



Comparisons with energy investments (left), and by region (right). Source: Slide 3 of Mr. van Ruijven's presentation; Andrijevic, M., Schleussner, C.-F., Gidden, M. J., McCollum, D. L. & Rogelj, J. COVID-19 recovery funds dwarf clean energy investment needs. Science (2020). DOI: 10.1126/science.abc9697

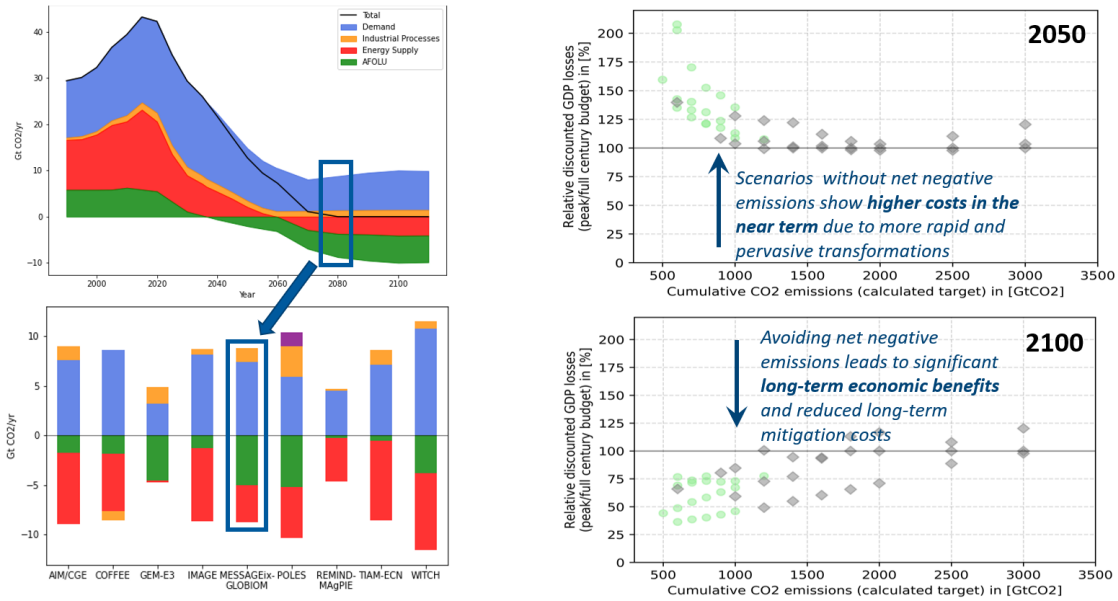
31. Multi-model comparisons of net zero emission scenarios were compared between those that limited warming to the Paris Agreement temperature limit without overshoot compared with scenarios that relied on net negative emissions to limit temperature by 2100 (figure 9). Different models agree that, even when net zero is achieved, there are several sectors that will still emit to 2100 - such as those involving demand and industrial processes. To achieve net zero, these sectors must be balanced out by the energy production and afforestation and land-use sectors.

32. Further details were also provided in the poster *The impact of COVID-19 and the greenness of recovery packages on climate change mitigation scenarios* (see paragraph 78 below).

Emission scenarios with limited or no use of negative emissions show higher costs in the short-term but greater long-term economic benefits than scenarios that include negative emissions

33. Some of the economic repercussions of the scenarios can be inferred by comparing changes in discounted GDP between full century budgets with scenarios for overshoot and net negative emissions, and peak warming scenarios with no overshoot or net negative emissions. Scenarios without negative emissions show higher costs in the near term (by 2050) due to more rapid transformations, but avoiding negative emissions leads to significant long-term economic benefits and reduced long-term (by 2100) mitigation costs.

Figure 9
Net-zero scenarios showing sectors that will continue to emit after net-zero is achieved and the costs of transformations that avoid a reliance on net negative emissions



Net-zero scenarios are in agreement on sectors that will continue to emit even when net-zero is achieved (left), and the short (2050) and long term (2100) costs of transformations that avoid a reliance on net negative emissions (right). Source: Slide 4 of Mr. van Ruijven's presentation; Riahi et al. Long-term economic benefits of stabilizing warming without overshoot – the ENGAGE model intercomparison. In press (2021). DOI: 10.21203/rs.3.rs-127847/v1

The transfer of good practices could be significantly helpful in bridging the emissions gap

34. The COMMIT project[26] have shown that, based on the emissions gap of the next few decades, current policies are insufficient to limit global warming to 2˚ C above preindustrial levels, nor is the current policy trajectory sufficient to meet the Paris Agreement temperature goal. The COMMIT project compared how countries can learn from each other and how best practices can be shared between them. This enables a 'bridging scenario' that bridges the gap between the Nationally Determined Contributions[27] and a 2˚ C

[26] See https://themasites.pbl.nl/commit/

[27] See https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs

scenario. It was found that the transfer of good practices is significantly helpful in bridging the emissions gap, with the greatest changes occurring in the energy supply sector, transport, and in non- CO_2 emissions.

35. Further details were also provided in the poster *Current action is not enough, but good practice policies can provide a bridge to the future* (see paragraph 79 below).

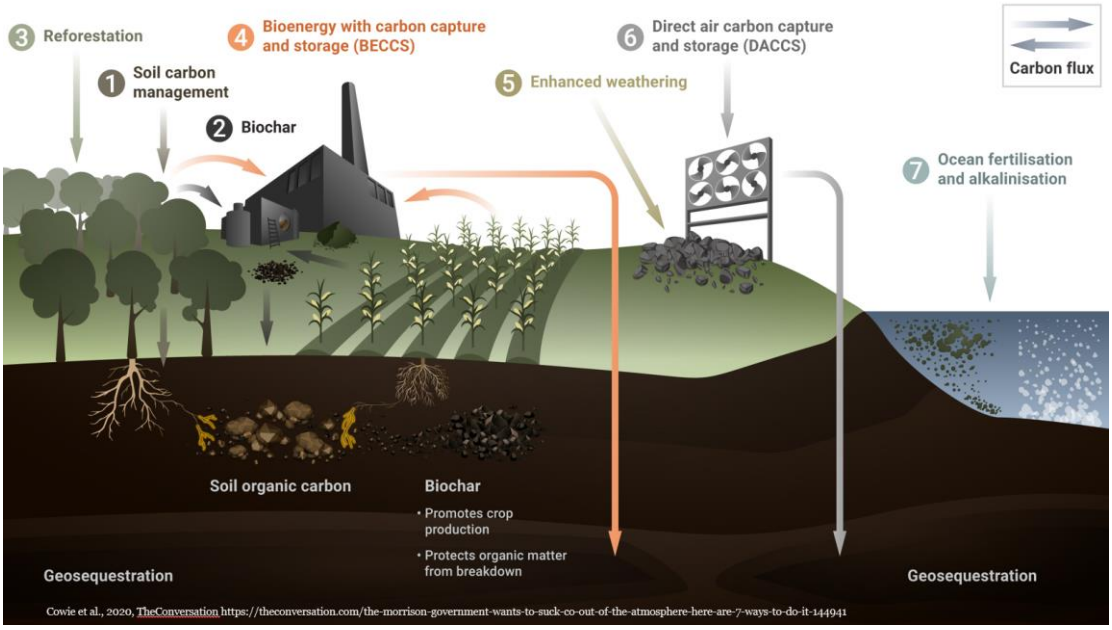
4. Opportunities, risks and benefits of CDR to reach net zero

36. Mr. Andy Reisinger, New Zealand Ministry for the Environment, presented on understanding the role of carbon dioxide removal (CDR) for global net-zero – opportunities, risks and benefits.

Carbon dioxide removal (CDR) is absolutely necessary for reaching net-zero CO2 emissions

37. As referred to above, the IPCC[28] defines CDR as anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. CDR includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage. It does not include natural CO_2 uptake that is not directly caused by human activity. There are a number of options for CDR (figure 10): 1) soil carbon management involves storing carbon using soil organic carbon management, afforestation, reforestation, and biochar; 2) biochar; 3) reforestation; 4) bioenergy with carbon capture and storage (BECCS) uses biological processes to capture the carbon from the atmosphere and then stores it in geological reservoirs; 5) enhanced weathering stores CO_2 via the chemical breakdown of rocks; 6) direct air carbon capture uses a technological or chemical process to store CO_2 in geological strata; and 7) there are also various ways of sequestering carbon dioxide in the ocean through marine primary productivity and durably storing it there.

Figure 10
Carbon Dioxide Removal methods

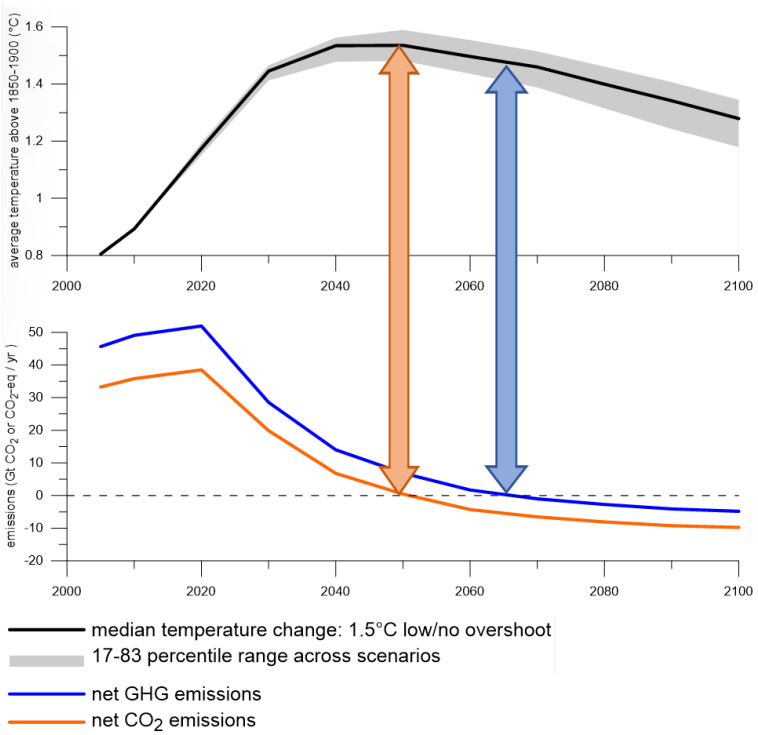


Source: Slide 4 of Mr.. Reisinger's presentation; Cowie et al. The Conversation (2020)

38. Mr. Reisinger emphasized that there is a difference between the timing of net zero CO_2 and net zero GHG emissions (figure 11). Achieving net zero CO_2 would roughly coincide with the timing of peak global temperature in stringent mitigation pathways. However, in these same pathways, when net zero greenhouse gas emissions are reached, temperature is already slowly declining. This equates to a 2-decade time difference between net-zero CO_2 and net-zero GHG in 1.5˚ C scenarios, and roughly a 3-decade time difference in 2˚ C scenarios.

[28] See https://www.ipcc.ch/sr15/

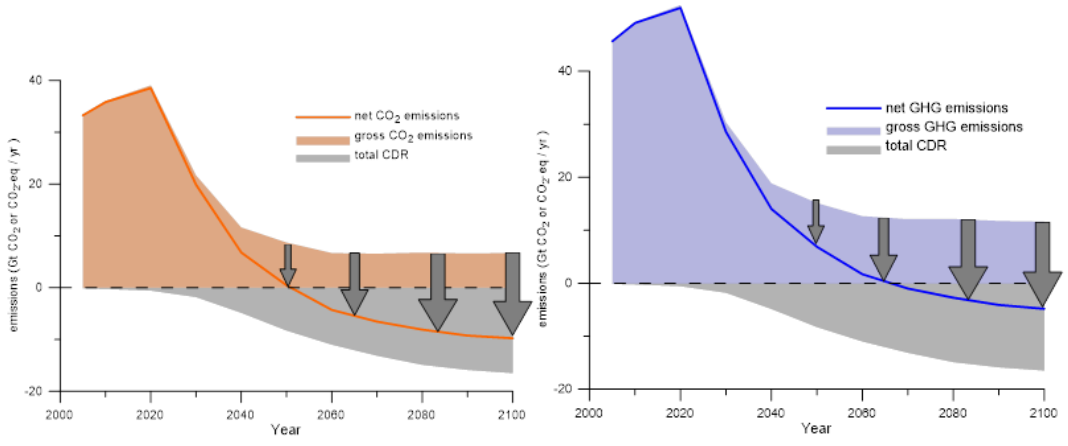
Figure 11
A comparison showing the different timings for reaching net-zero GHG and net-zero CO2 emissions for the median temperature change in a 1.5˚C low or no overshoot scenario



Illustrated for pathways with low/no overshoot of 1.5°C; scenarios. Source: Slide 6 of Mr Reisinger's presentation; Rogelj, J. et al. IPCC Special Report on Global Warming of 1.5 ºC, Chapter 2. (2018); Huppmann, D. et al. The MESSAGEix Integrated Assessment Model and the ix modeling platform (ixmp): An open framework for integrated and cross-cutting analysis of energy, climate, the environment, and sustainable development. Environmental Modelling & Software (2019). https://doi.org/10.1016/j.envsoft.2018.11.012

39. For example, figure 12 shows an example pathway to net zero CO_2 achieved using substantial CDR beginning around 2020 for a temperature limit of 1.5°C: a) CDR is initially used to achieve net zero CO_2 and then to achieve net negative CO_2 emissions as compensation for hard to abate residual CO_2 emissions; b) the same amount of CDR is also used to achieve net zero greenhouse gas emissions, though this occurs later, as removals are not sufficient to achieve net zero greenhouse gas emissions by 2050 in this scenario. Net negative GHG emissions is achieved with increasing use of CDR to achieve a faster rate of temperature decline towards 2100.

Figure 12
Example pathway for net-zero emissions with CDR

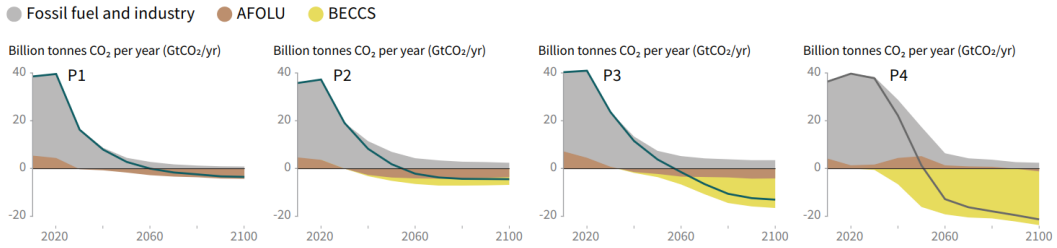


Net zero CO2 emissions (above) and net zero GHG emissions (below). Illustrated for pathways with low/no overshoot of 1.5°C. scenarios. Source: Slides 10-11 of Mr. Reisinger's presentation; ibid

Reliance on CDR grows with every tonne of CO_2 emitted

40. All mitigation pathways assessed in SR1.5 for net-zero CO_2 rely on CDR to some extent, although different mitigation strategies for net-zero differ in their reliance on CDR, as some emission sources are too difficult to abate by 2100. The IPCC SR1.5 explored example strategies for net-zero, 4 illustrative pathways are shown in figure 13. Strategies with a rapid reduction in gross emissions and low residual emissions require less CDR than in scenarios with delayed emissions reductions and higher residual emissions. Reliance on CDR grows with every ton of emissions The CDR technology mix also differs in these scenarios ((AFOLU, BECCS, DAC, other …), as does the rate of decline after the temperature peak.

Figure 13
Illustrative pathways from IPCC Special Report on Global Warming of 1.5 ºC



Source: Slide 12 of Mr. Reisinger's presentation; Rogelj et al. IPCC Special Report on Global Warming of 1.5 ºC, Chapter 2. (2018)

All CDR options have limits and potential for negative side-effects that grow with the scale of implementation

41. There are a range of CDR options available (figure 14) but large imbalances and asymmetries exist between different CDR options in terms of:

a). Maturity -For example, afforestation and reforestation techniques are relatively well established, while ocean fertilization is still in its experimental stages;

b). Permanence - Soil carbon sequestration is highly reversible, whereas storage in geological reservoirs is more durable;

c). Effectiveness - some options only deliver small-scale removals, others provide much larger scale CDR;

d). Cost and potentials - vary depending on a range of factors and scales;

e). Actors and governance - especially if CDR is undertaken at large scales then new alliances are required. For example, bioenergy, crop production and CCS require new forms of governance whereas afforestation or soil carbon sequestration lie within existing practice systems.

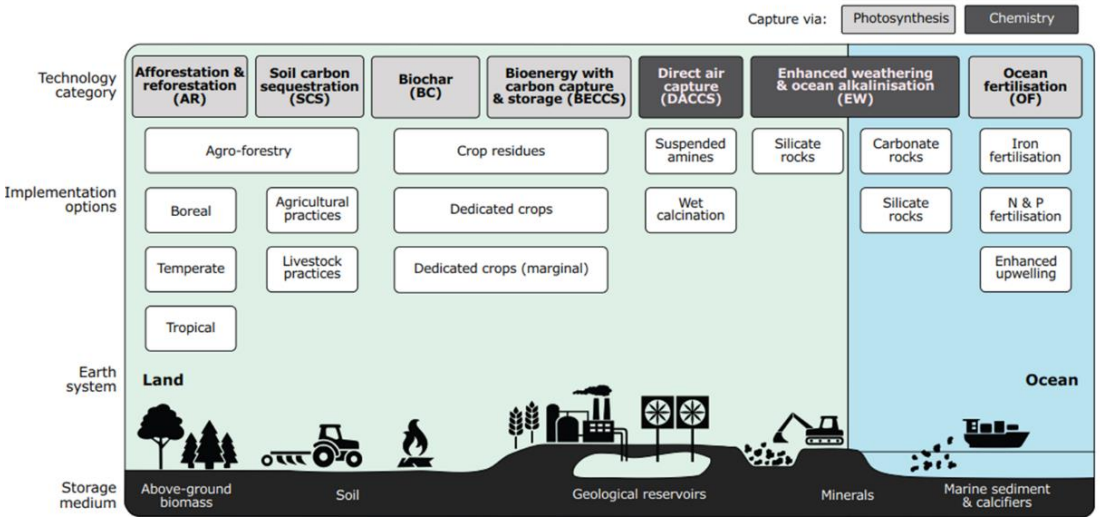
42. Use of CDR also interacts with other sustainable development objectives (figure 15). All CDR options rely on land, water, energy, or marine net primary production. This places additional pressure on the carbon storage capacity of the associated ecosystems and ecosystem services, for example:

a). Direct air capture with CCS requires a substantial amount of energy to operate but has a very large sequestration potential;

b). Bioenergy with CCS can produce large amounts of energy but requires more land and water to produce bioenergy crops;

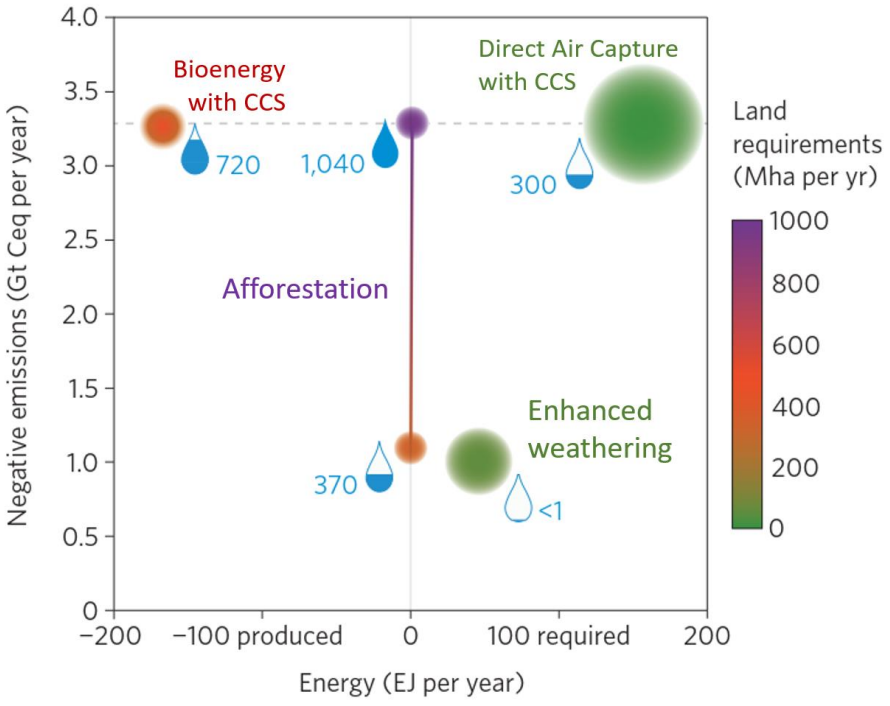
c). Afforestation neither produces nor requires large amounts of energy, but has a very large carbon footprint, especially if it is to match the mitigation capability as direct air capture or BECCS.

Figure 14
Options for CDR



Source: Slide 16 of Mr. Reisinger's presentation; Minx J.C. et al. Negative emissions—Part 1: Research landscape and synthesis. Environmental Research Letters (2018). https://doi.org/10.1088/1748-9326/aabf9b

Figure 15
Graphing the trade-offs between BECCS and ecosystem services



Source: Slide 15 of Mr.. Reisinger's presentation; Smith, P., Davis, S., Creutzig, F. et al. Biophysical and economic limits to negative CO2 emissions. Nature Climate Change (2016). https://doi.org/10.1038/nclimate2870

Choices around how much CDR, when, and how, need to become core parts of climate policy to reduce over-reliance and forced trade-offs

43. Mr. Reisinger highlighted that it is difficult to give high-level global assessments of how CDR options interact with SDGs and other objectives. Global assessments provide limited guidance, as interactions depend on local context and on both the mode and scale of implementation.

44. The SRCCL illustrated how bioenergy and BECCS can have potentially negative implications for food security if implemented at large scales without additional constraints, and presented potential trade-offs with adaptation, land degradation, and desertification. However, if carried out, as per best practices, at smaller scales and strongly embedded within sustainable land management practices, there could be strong synergies with quite minor trade-offs with food security.

45. Similar considerations apply for reforestation and forest restoration which could result in potential detrimental impacts at large scales but, if strongly embedded in climate and/or land management practices, trade-offs can be managed and even turned into synergies.

Net zero is not the end goal of climate policy

46. It is important to note that net-zero is not the end goal. The higher the residual gross emissions are when net zero is reached, the more continued CDR at continued cost is required to maintain net zero. There is also a risk of saturation and the reversal of carbon storage in reservoirs, particularly in biological reservoirs such as the ocean. Additionally, some global or national net-zero targets imply that some actors must sustain net-negative emissions while others are still net-positive. To achieve the global, and even some national targets, some actors are required to achieve net negative emissions far sooner than global the net negative target is achieved.

Investments in R&D and pilot projects as well as appropriate institutional and governance frameworks are needed to match the required reliance on CDR

47. CDR is necessary for net-zero as there will be emissions that are too hard to abate. There will be remaining gross emissions even in a net-zero world, and the timing and scale of CDR differs between net-zero CO_2 and net-zero GHG emissions and depends on how we approach gross emissions. All CDR options have limits and the potential for negative side effects that grow with the scale of implementation. Choices must be made regarding how much CDR is used, when, and what types are needed so that they can become a core part of climate policy and reduce over-reliance and forced trade-offs. Currently, investments in R&D pilots, upscaling, institutions, governance, and the embedding of CDR in development plans do not match what will be needed based on our future reliance on CDR.

5. Scientific and societal assessment of potential ocean interventions for climate change mitigation

48. Mr. Chris Vivian, Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) Working Group 41[29] on ocean interventions for climate change mitigation, presented on the scientific and societal assessment of potential ocean interventions for climate change mitigation in a joint presentation from GESAMP, IOC, IMO, WMO and Carnegie Climate Governance Initiative (C2G). The information presented was further detailed in a poster *GESAMP Working Group 41 on Ocean Interventions for Climate Change Mitigation -Potential contribution for enabling ocean carbon dioxide removal to achieve net zero and green recovery* (see paragraphs 80 below).

49. GESAMP Working Group 41 has two objectives: to better understand the potential environmental and socioeconomic impacts of different marine climate intervention approaches; and to provide advice to the London Protocol[30] Parties to assist them in identifying those marine climate intervention techniques that might be sensible to consider for listing in the 2013 amendment to the Protocol to regulate the placement of matter for ocean fertilization and other marine geoengineering activities (resolution LP.4(8)), referred to as Annex 4 of the LP.

50. GESAMP does not promote the mitigation techniques assessed. The group was formed out of concern for the protection of the marine environment from activities that might otherwise go ahead without any assessment or control.

[29] See http://www.gesamp.org/work/groups/41
[30] See https://www.imo.org/en/OurWork/Environment/Pages/EmergingIssues-default.aspx

A number of ocean interventions have been proposed for climate change mitigation, including CDR, but there is currently insufficient knowledge on these interventions for evidence-based decision making

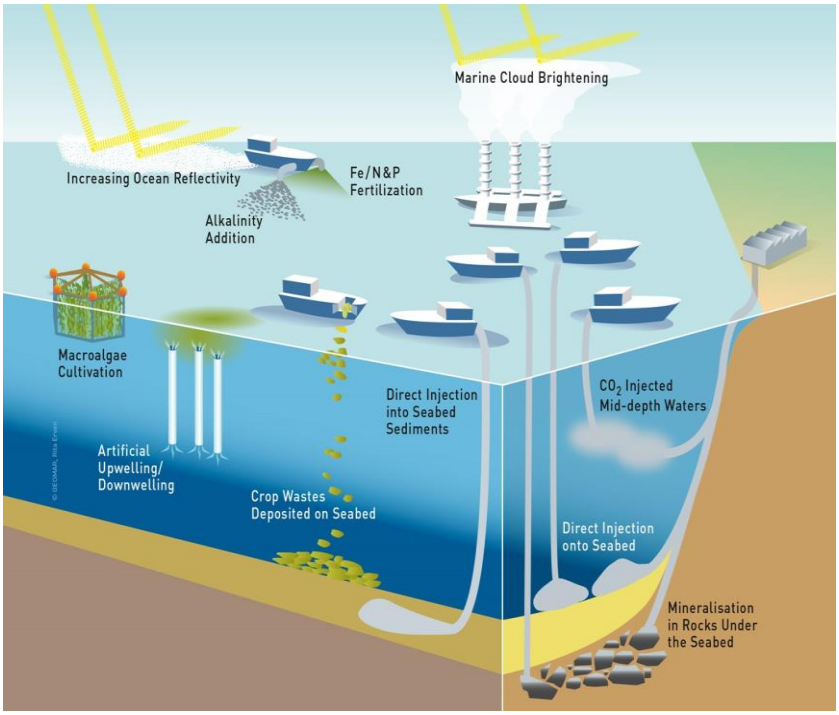
51. Mr. Vivian explained that the marine environment is considered suitable for a range of mitigation approaches for two reasons. Firstly, the vast scale, depth, and surface area of the ocean create the potential to devise and develop marine climate intervention approaches. Secondly, about 25% of anthropogenic CO_2 emissions are taken up by the ocean and over the last 20 years proposals have emerged on the potential to enhance this uptake.

52. WG41 published the *High-level review of a wide range of proposed marine geoengineering techniques* in 2019.[31] This was the first study to comprehensively examine the many proposals which involve using the marine environment to recover CO_2 from the atmosphere, boost the reflection of incoming solar radiation to space (albedo modification), or in some cases both. The assessment catalogued 27 approaches and detailed 8 illustrative examples of Carbon Dioxide Removal (CDR), Albedo Modification (AM) and hybrid technologies extending beyond CDR and albedo modification. The assessment framework for ocean fertilisation developed by the London Convention and Protocol Parties was used as a template for assessing the different approaches in the study. Information available on the approaches varied widely from concepts to multiple scientific papers.

53. The report shows that there is insufficient information available on the approaches examined to permit a robust scientific assessment and therefore insufficient knowledge for evidence-based decision-making. The working group did not find compelling evidence for the practical implementation of any marine climate intervention techniques for enhancement of carbon sequestration by the ocean.

54. Despite the widespread knowledge gaps, the report authors provided an evaluation of eight illustrative marine geoengineering approaches (some of the approaches are illustrated in figure 16) using the most applicable and pertinent criteria from prior reports bolstered with additional essential criteria. The most important of these criteria was the availability of information on the performance and impacts of these approaches as attained by scientific testing and experimentation.

Figure 16
Examples of marine geoengineering approaches assessed in *High-level review of a wide range of proposed marine geoengineering techniques*



Source: Slide 2 of Mr. Vivian's presentation; Boyd, P. et al. High level review of a wide range of proposed marine geoengineering techniques (2019). DOI: 10.13140/RG.2.2.29818.03528

[31] Available at http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques

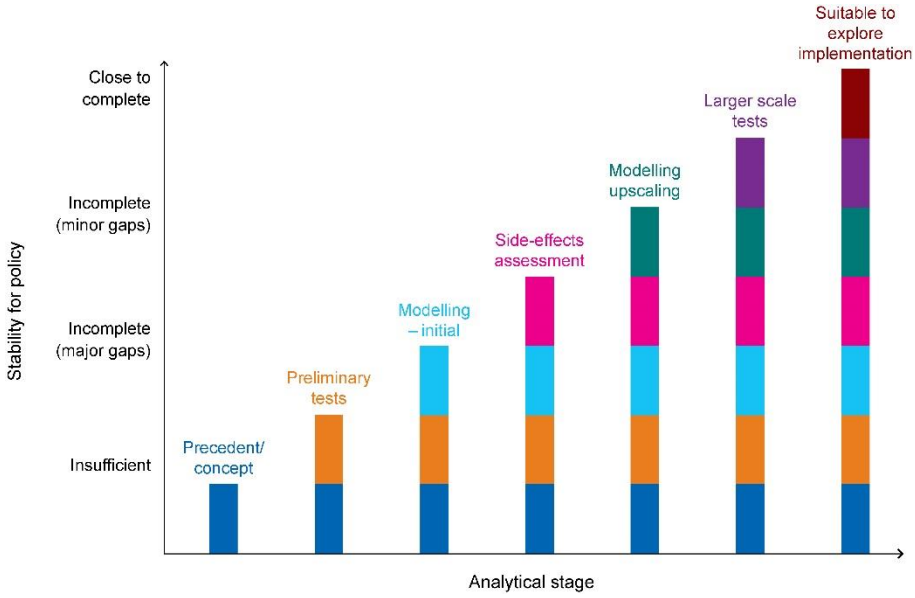
Frameworks are needed for research on ocean interventions for climate change mitigation and for coordinated reporting of approaches

55. Key recommendations from the report include:

a). Develop a coordinated framework for proposing marine climate intervention activities, submitting supporting evidence, and integrating independent expert assessment must be developed. A framework for analysis is provided in the report (see figure 17) which also highlights that incentives should be considered for proposers of ocean interventions for climate change mitigation to comprehensively report their approaches in the permanent public record.

b). Develop a framework to integrate inputs from natural sciences and societal disciplines into a holistic assessment of ocean interventions for climate change mitigation or other purposes consistent with the London Protocol's definition of marine geoengineering, to be used by regulators, policy-makers, funders or anyone considering or permitting proposals, exploring the use of a systems approach framework e.g. Elliott et al. (2020).[32]

Figure 17
Proposed framework for analysis of marine climate intervention activities



Hypothetical plot to explore in detail the relationship between suitability for policy (from insufficient to near-complete) in relation to stage of the analysis. The graduations across "Analysis Stage" are based largely on the evolution of research into ocean iron fertilization.

Source: Slide 7 of Mr. Vivian's presentation; Boyd, P. et al. High level review of a wide range of proposed marine geoengineering techniques (2019). DOI: 10.13140/RG.2.2.29818.03528

56. As part of its new terms of reference, GESAMP working group 41 will stimulate information gathering to fill the previously mentioned knowledge gaps and enable robust scientific assessment and improved modelling simulations at the ocean basin scale and at decadal timescales. This requires better dialogue between modellers, the systematic observation and research communities to improve model accuracy.

57. Examples of research projects already addressing knowledge gaps include:

a). The Surface Ocean Lower Atmosphere Study[33] (SOLAS) which aims to understand the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and how these affect and are being affected by climate and environmental change;

[32] See Elliott, M., Borja, A. and Cormier, R. Managing marine resources sustainably: A proposed integrated systems analysis approach. Ocean and Coastal Management (2020). https://doi.org/10.1016/j.ocecoaman.2020.105315
[33] See https://www.solas-int.org/

b). The WCRP Carbon Dioxide Removal Model Intercomparison Project[34] (CDR-MIP) embeds Earth-system models in a common framework to explore the potential impacts and challenges of CDR. CDR-MIP experiments include CDR induced climate 'reversibility' and the CDR potentials of proposed approaches, for example ocean alkalinisation.

Current knowledge of the ocean carbon system and its biological component are insufficient to assess consequences of CDR – a holistic coordinated response is proposed by IOC-R

58. Mr. Vivian outlined that current knowledge and understanding of the ocean carbon system, and in particular its biological component as well as the land-coastal ocean-open ocean continuum, are currently inadequate to determine efficacy, quantification, and consequences of ocean-based carbon dioxide removal (CDR). A holistic view is needed that will be provided by the Integrated Ocean Carbon Research (IOC-R). IOC-R is an ambitious initiative led by IOC and bringing together the Integrated Marine Biosphere Research[35] (IMBeR), CLIVAR[13], SOLAS, the Global Carbon Project[36], and the Integrated Ocean Carbon Coordination Project.[37] In conjunction with the launch of the UN Decade on Ocean Science for Sustainable Development in January 2021, the IOC-R will provide "A Summary of Ocean Carbon Research, and Vision of Coordinated Ocean Carbon Research and Observations for the Next Decade".[38]

Governance should be an important element of future assessment and research of marine CDR

59. Mr. Vivian concluded by outlining some key challenges for marine CDR governance. He stated that governance will be an important element of future assessment and research. Marine CDR could occur within territorial seas, exclusive economic zones, or the global commons. Each area raises different sets of governance issues. Effective governance and research, testing, deployment, and monitoring would likely include broad participation in decision-making and regulation at the international, national, and sub-national levels. Some CDR techniques also have transboundary impacts requiring international governance via governments at all levels. Key challenges include:

a). Ensuring appropriate codes for conduct, safeguards and policy direction for research;

b). Monitoring and attribution of impacts;

c). Aligning multiple applicable governance frameworks;

d). Effectively engaging stakeholders in meaningful dialogue;

e). Resolving who decides when/if/under what conditions to move from research to deployment;

f). Understanding the balance between the potential for harm and benefits of deployment.

60. A number of Conventions and Agreements require a coordinated framework in which to respond to these challenges: the Convention on Biological Diversity[39]; the London Protocols and the London Convention on the prevention of marine pollution 1972[30]; the UN Convention on the Law of the Sea[40] (UNCLOS), the UNFCCC[41], the UN General Assembly[42], civil society organisations, the commercial sector, the research community, and regional bodies such as the Arctic Council[43] and the regional seas conventions[44].

[34] See https://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/cmip6-endorsed-mips-article/1302-modelling-cmip6-cdrrmip
[35] See http://imber.info/
[36] See https://www.globalcarbonproject.org/
[37] See https://www.uk-ioc.org/IOCCP
[38] See https://www.essoar.org/pdfjs/10.1002/essoar.10504934.1
[39] See https://www.cbd.int/
[40] See https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf
[41] See https://unfccc.int
[42] See https://www.un.org/en/ga/
[43] See https://arctic-council.org/en/
[44] See https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/regional-seas

6. Updates on biodiversity loss and transitions needed for a sustainable future

61. Mr Hesiquio Benitez Diaz, CBD SBSTTTA Chair, presented on the outcomes of the 5th Global Biodiversity Outlook[45] (GBO5), providing the latest research on the connections between biodiversity and climate change, and the transition to a more sustainable future. GBO5 is composed of three sections: Biodiversity for Sustainable Development, Progress towards the Aichi Biodiversity Targets, and Pathways to the 2050 Vision for Biodiversity[46]. Mr. Diaz emphasized the close relationship between climate change, the SDGs and biodiversity, and how healthy biodiversity can help respond to climate change and how responding to climate change needs healthy biodiversity.

Biodiversity, and the services it provides, are in a serious rate of decline

62. GBO5 reports that none of the CBD Aichi targets have been achieved. Aichi targets 5, 10 and 15 are examples of targets particularly related to work on climate change:

a). Target 5 "By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced" – research results show that the annual rate of global forest expansion and deforestation illustrates a globally important loss of biodiversity due to changes in tree cover from tropical primary forests and in the extent of natural wetlands. This translates to a global loss of biodiversity and carbon sinks.

b). Target 10 "By 2015, the multiple anthropogenic pressures on coral reefs and other vulnerable ecosystems impacted by climate change or ocean acidification are minimised so as to maintain their integrity and functioning" - the probability of coral bleaching has been increasing as the oceans warm and the carbonate that forms the basis of coral dissolves (as also highlighted in the IPCC SROCC).

c). Aichi target 15 "By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced though conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification" – here also results show progress is limited, although there are ambitious restoration programmes underway or proposed in many regions, with the potential to deliver significant gains in ecosystem resilience and preservation of carbon stocks..

It is not too late to slow, halt and eventually reverse current trends in the decline of biodiversity and the actions needed are fully consistent with the Paris Agreement

63. Available evidence suggests that despite the failure to meet the goals of the Strategic Plan for Biodiversity 2011-2020, it is not too late to slow, halt and eventually reverse current trends in the decline of biodiversity. Moreover, the actions required to achieve this turnaround (or 'bending the curve' of biodiversity decline, as it has been termed), are fully consistent with, and indeed crucial components of, the goals and targets set out under the 2030 Agenda for Sustainable Development and the Paris Climate Change Agreement.

64. Efforts to keep climate change well below 2°C and close to 1.5°C above pre-industrial levels are needed to prevent climate impacts from overwhelming all other actions in support of biodiversity. The conservation and restoration of ecosystems can play a substantial role in this. Nature-based solutions can also be an important part of responses to climate change.

Substantial changes, innovations, and a portfolio of actions implemented on a short timescale and involving a wide range of actors across all scales and sectors is needed

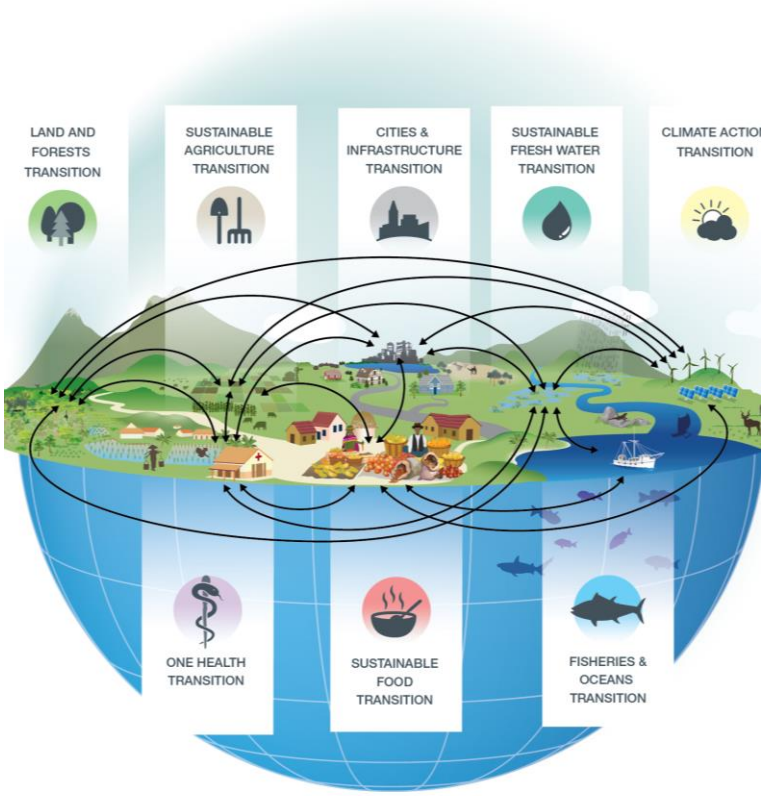
65. GBO5 proposes a sustainable climate action transition: employing nature based solutions, alongside a rapid phase-out of fossil fuel use, to reduce the scale and impacts of climate change, while providing positive benefits for biodiversity and other sustainable development goals. This transition recognizes the role of biodiversity in sustaining the capacity of the biosphere to mitigate climate change through carbon storage and sequestration and in enabling adaptation through resilient ecosystems, as well as the need to promote renewable energy while avoiding negative impacts on biodiversity.

66. The research shows eight inter-related transitions to living in harmony with nature, compatible with the 'nexus' approach outlined in the IPBES Global Assessment (figure 18): Land and Forests; Freshwater;

[45] Available here: https://www.cbd.int/gbo5
[46] See https://www.cbd.int/sp/

Fisheries and Oceans; Sustainable Agriculture; Food Systems; Cities and Infrastructure; Climate Action; and One Health.

Figure 18
Transitions in eight aspects of the interface between human activity, human well-being and nature



Source: Slide 14 of Mr. Benitez' presentation; Secretariat of the Convention on Biological Diversity. Global Biodiversity Outlook 5. (2020)

Increased collaboration between UNFCCC and the CBD, and IPCC and IPBES, is needed

67. Mr Benitez concluded by emphasizing the need to work together to achieve the vision of living in harmony with nature. Acting on climate change is a key element of this. The importance of coordination between the UNFCCC and the CBD has been noted in decisions and recommendations under the Convention, its subsidiary bodies, and by the COP. The CBD, UNFCCC, IPCC, and IPBES organised a workshop on biodiversity and climate change: integrated science for coherent policy in 2018. The CBD post-2020 process provides one of a range of opportunities for greater collaboration on biodiversity/climate change related issues.

Summary of Discussions

68. **Will the WCRP lighthouse activities focus on the regional scale?**

*Mr Mike Sparrow:*The WCRP has started regional consultations which will continue over several months starting in December 2020. The WCRP will also examine needs at local and regional scale including through regional climate fora linked to other activities such as the WMO regional climate outlook for a. Concept notes for the lighthouse activities are still being developed and available on the WCRP website. The science plans will be written over a period of six months by a diverse team of authors.

69. **Will the WCRP engage with Africa as a whole or with specific regions?**

Mr Mike Sparrow: During initial consultations, the WCRP received a lot of input from Southern African states but not as much from other regions. There is a recognised need to engage with the rest of the African continent and also ensure that the science and services foci cover the entirety of the African Continent.

70. **Does WASP work at the regional level and/or envisage any outreach to technology transfer and capacity-building bodies such as the Climate Technology Centre and Network, the Technology Executive Committee, or the Paris Committee on Capacity-building?**

Ms. Chen: There is a connection between WASP's regional work and its outreach to bodies focusing on technology transfer and capacity-building. UNEP, WASP and APAN work closely together closely. In terms of working with other bodies, WASP is aiming to enhance its collaboration with the UNFCC bodies including the Climate Technology Centre and Network[47] (CTCN) and Paris Committee on Capacity-building[48] (PCCB) to enhance adaptation on the ground.

Mr. Patwardhan: WASP sees itself as a network of networks that looks to build new linkages and we invite further conversation on doing so.

71. **What methodological progress has been made in the assessment of the level of resilience in different systems?**

Mr. Patwardhan: There is now understanding in characterizing the resilience of systems and identifying key vulnerabilities. A key notion is the concept of systemic risk, as highlighted by the pandemic. One of the policy briefs examines transboundary risk and how we perceive systemic risk.

72. **How is WASP focusing on adaptation action and gender equity impacts?**

Mr. Patwardhan: While the overall objective of WASP is to identify the knowledge and information required to support action, a lot of work revolves around making risk visible and characterizing who is at risk and why. Gender is therefore important to WASP's work as there are many differentiated vulnerabilities and impacts. WASP aims to emphasise this area through its research and knowledge products.

73. **If the pandemic is related to a reduction in greenhouse gas emissions, are these reductions seen globally or in specific places?**

Mr. van Ruijen: Research on the COVID-19 recovery is still ongoing. In principle, there is potential to recover better from the crisis globally. However, places where the crisis hit harder and where there is more rebuilding to do have a larger potential to use this opportunity to change trajectory.

74. **What sectors have remaining emissions at net zero since these are consistent sectors that can be targeted for research?**

Mr. van Ruijen: Some sectors will find it far harder to abate and reach net zero emission, such as some industrial processes or in places which are not easily electrified or where electrification achieving carbon neutrality is expensive. These sectors have significant impact on the cost of mitigation overall particularly negative emissions in the electricity sector.

75. **Can you please elaborate on the risks of CDR for the SDGs?**

Mr. Reisinger: There is a range of risks of CDR for the SDGs. A key risk that has received some research attention is food security, as growing bioenergy through a BECCS route will require the use of large amounts of land to grow the bioenergy crops. There are also risks from relying on large-scale afforestation as the land to be planted may already being used for agricultural practice which creates risks for the livelihood of affected communities. CDR is also an economic problem, for example if agricultural land is used for afforestation this land may have marginal productivity but often supports marginalized communities. Livelihoods need to be considered as part of just transitions.

There are also considerations of water use in various CDR options and the creation of new transfers involved between different actors in CDR value chains. Water use-related risk depends on the local implementation of different CDR options and how CDR strategies are embedded in other land management strategies, energy strategies, or the creation of new value chains.

76. **Why should we consider ocean climate interventions and should they be considered as adaptation rather than geoengineering? Why was GESAMP renamed from marine geoengineering to ocean interventions for climate change mitigation?**

Mr. Vivian: GESAMP's name changed because the term geoengineering has become a term of abuse from some groups or confusing for others who define geoengineering only as referring to atmospheric techniques. Geoengineering has referred to geotechnical engineering, ie. in the Earth

[47] See https://www.ctc-n.org/
[48] See https://unfccc.int/pccb

for decades, so its terminology in the climate change context is incorrect. Other groups have also switched to using similar terminology, such as the Carnegie Climate Governance Initiative.

There have been several papers that have reviewed how to categorise techniques in terms of mitigation or adaptation and concluded that several of these techniques are really only a type of mitigation as they are aim to enhance natural sinks.

B. Poster Session

77. Six posters were presented on Theme 1 to complement the information provided in the presentations. All posters can be viewed via the UNFCCC website for the twelfth meeting of the research dialogue[49] with accompanying audio commentary, or individually via a hyperlink in each title below. Presenters are listed below while the full list of authors is listed on each poster.

78. **The impact of COVID-19 and the greenness of recovery packages on climate change mitigation scenarios**

Bas van Ruijven (IIASA), Charlie Wilson (UEA), Valentina Bosetti (CMCC), Johannes Emmerling (PIK); Silvia Pianta, Massimo Tavoni (RFF-CMCC); Panagiotis Fragkos (E3M), Jean Francois Mercure (University of Exeter); Ioannis Dafnomilis, Michel den Elzen, Heleen van Soest (PBL); Frederic Hans, Takeshi Kuramochi, Niklas Höhne (NewClimate Institute); the ENGAGE and NAVIGATE consortia. Integrated Assessment Modelling Community

Modelling results were presented from the NAVIGATE[50] and ENGAGE[51] consortia on the projected impacts of COVID-19 and the greenness of recovery packages. As referred to also in the presentation above (see paragraphs from 29-35), results from mitigation scenarios have shown impacts on:

- The economy, labour market and structural changes (both demand and supply side) – Preliminary analyses show that green stimulus packages can boost growth and employment while substantially reducing emissions and contributing to meeting climate targets in the post-COVID era.
- Demand and lifestyles – COVID-19 has major direct implications on people's lifestyles (lockdowns, travel restrictions, teleworking) in the short- to medium term, although longer-term implications are uncertain. The NAVIGATE project are developing a conceptual framework to monitor the impacts of the COVID pandemic and recovery on lifestyles and energy demand.
- Emission pathways - The greenness of recovery packages is a decisive factor in future emission reductions.

  Calculations indicate that the general slowdown of the economy would lead to an annual global emission reduction of –4% to –7% by 2030, compared to recent pre-COVID policy projections in the IMF's Baseline and Longer and New Outbreak scenario, respectively. A rebound to fossil fuels, with lower decarbonisation rates, however, would result in fewer emission reductions (-5%) by 2030 or potentially an increase in emissions (+1%).

  Assuming green recovery scenarios with 4%-6% decarbonisation between 2021-2023 based on full implementation of IEA's Sustainable Recovery Plan (2020) would reduce GHG emissions much more drastically. Those projections would be more in line with the aim of keeping the 1.5˚ C and 2˚ C targets in reach.
- Inequality – In 2020, an additional 70 million people are projected to live in poverty, notably in Africa and India. Inequality rose significantly in 2020, especially in developing countries. Past pandemics have had significant impacts on economic sustainability, resulting in increased inequality, unemployment, and poverty, as well as having a persistent impact on GDP. It is thus important that policies are designed to address these multi-dimensional impacts.
- Climate change mitigation efforts – A survey of 223 policymakers and stakeholders from 55 countries was taken during 2020 asking their expectations concerning the likely medium-term impact of the COVID-19 crisis and its economic implications on climate policy. The survey suggests that experts have relatively positive outlooks, expecting the COVID-19 pandemic to open a window of opportunity for more ambitious climate action, albeit with sectoral & country differences. Experts from developed countries expect a more pronounced strengthening of climate

[49] See https://unfccc.int/topics/science/events-meetings/research-dialogue/twelfth-meeting-of-the-research-dialogue
[50] https://iiasa.ac.at/web/home/research/researchPrograms/Energy/Research/NAVIGATE.html.
[51] https://www.engage-climate.org/.

policy; views on developing countries are more uncertain. The experts also expect that public attitudes will shift in favour of climate change mitigation.

79. **Current action is not enough, but good practice policies can provide a bridge to the future**

Detlef van Vuuren (PBL), Heleen van Soest (PBL), Roberto Schaeffer (COPPE), Keywan Riahi (IIASA), Elmar Kriegler (PIK); The COMMIT and CD-LINKS consortia. Integrated Assessment Modelling Community

Results from the COMMIT and CD LINKS[52] consortia show that closing the remaining emissions gap between NDCs and the global emissions levels needed to achieve the Paris Agreement's climate goals will likely require a comprehensive package of policy measures. National and sectoral policies can help fill the gap, but success stories in one country cannot be automatically replicated in other countries, and need to be adapted to the local context.

A new Bridge scenario was developed based on nationally relevant measures informed by interactions with country experts. This scenario was implemented with an ensemble of global integrated assessment models (IAMs). This showed a global roll-out of these good practice policies closes the emissions gap between current NDCs and a cost-optimal well below 2 °C scenario by two thirds by 2030 and more than fully by 2050, while being less disruptive than a scenario that delays cost-optimal mitigation to 2030.

The Bridge scenario leads to a scale-up of renewable energy (reaching 50%-85% of global electricity supply by 2050), electrification of end-uses, efficiency improvements in energy demand sectors, and enhanced afforestation and reforestation. The analysis suggests that early action via good-practice policies is less costly than a delay in global climate cooperation.

80. **GESAMP Working Group 41 on Ocean Interventions for Climate Change Mitigation - Potential contribution for enabling ocean carbon dioxide removal to achieve net zero and green recovery**

Chris Vivian, GESAMP Working Group 41

Parties to the London Convention and London Protocol first expressed concern about the marine environmental impacts of a marine geoengineering activity in 2007 due to a proposed ocean fertilization activity planned by the US Company Planktos. Subsequently, the London Protocol was amended in October 2013 to regulate ocean fertilization activities and to enable Parties to regulate other marine geoengineering activities in future.

The poster summarises the main points from the 'High level review of a wide range of proposed marine geoengineering techniques (as outlined in paragraphs 48-60 above) and briefly introduces the next phase of work agreed by GESAMP.

- The report was the first dedicated assessment of the wide range of proposed marine geoengineering approaches.
- It catalogues 27 approaches from categories spanning Carbon Dioxide Removal (CDR), Albedo Modification (AM) and hybrid technologies.
- The information available on proposed techniques varied widely ranging from initial concepts to ones with multiple scientific papers.
- For all techniques, information on approaches available in the permanent public record, and/or as peer-reviewed documents, is inadequate to permit a robust scientific assessment, much less one that can be readily intercompared with other approaches to climate intervention.
- Although decisions on policy formulation or governance are often based on incomplete information, for many of the approaches examined the knowledge available was viewed to be insufficient for evidence-based decision-making.
- These major gaps raise issues regarding the ability to effectively communicate the aspects of geoengineering to policy makers and the general public.
- If we do not have adequate scientific knowledge about a technique, then it is very difficult to assess the relevant societal issues such as governance, social licence etc for a technique.
- The report provided guidelines for proponents on the series of steps needed to support an evidence-based assessment.

[52] https://www.cd-links.org.

In order to enable a thorough scientific and societal assessment of potential ocean interventions for climate change mitigation so that their potential contribution to net zero and green recovery can be reliably evaluated, the report made recommendations that have been adopted into new Terms of Reference for the Working Group, in particular:

- To develop a framework to integrate inputs from natural sciences and societal disciplines into a holistic assessment of ocean interventions for climate change mitigation.
- To stimulate information gathering to fill the knowledge gaps, enabling robust scientific assessment and improved modelling simulations, at the scale of ocean basins and multiple decades, to look at spatial and temporal extrapolation of climate intervention approaches.
- To encourage a stronger dialogue between modellers and scientists (conducting lab and field studies) to improve model accuracy and hence reduce uncertainties in projections.

81. **Navigating Climate Neutrality: A Framework for Local and Regional Governments to Achieve Net Zero GHG Emissions**

Pourya Salehi, Maryke van Staden, Yunus Arikan; ICLEI - Local Governments for Sustainability (World Secretariat)

In response to the global climate emergency, ICLEI launched a Climate Neutrality Framework, calling for the necessary level of ambition and daring leadership in all cities, towns and regions around the globe, whether urban or rural.

The Framework is built on ICLEI's three pillars of climate neutrality: i) drastically Reduce GHGs; ii) divest, repurpose, and reinvest; and iii) offset and compensate GHGs.

As part of this work, ICLEI's carbon Climate Registry (cCR) provides governments with a platform for tracking action, in a way that is transparent and credible. It is essential that governments have access to accurate data as this informs strategies to reduce GHG emissions.

As part of its support to UNFCCC Race-ToZero Campaign, and through its Climate Neutrality Framework, ICLEI will seek to:

- Ensure acknowledgment of the existing climate neutrality commitments;
- Increase the number of cities and regions that are committing to climate neutrality;
- Encourage its members and network to consider re-assessment, recalculation or recalibration of their existing climate neutrality targets with the Science-Based-Targets Approach towards and beyond COP26 in 2021;
- Support monitoring progress & compliance.

82. **Carbon Dioxide Removal: Boosting promising approaches indispensable to meet Swiss and global climate targets**

Switzerland / Federal Office for the Environment FOEN

The poster outlines the work of Switzerland in responding to net-zero and the role of CDR. It highlights the gaps in knowledge and requests closer coordination between the scientific community to support policymakers for a better understanding of the challenges and solutions concerning CDR.

Research gaps and needs include:

- Understanding the challenges and opportunities (environment, politics, research, industry, society) locally, nationally and internationally;
- Technology portfolios according to national conditions;
- Reduction and possibly removal targets in accordance with 1.5 degrees;
- Evaluation of research and development as well as pilot projects, scale - up options, market conditions and social acceptance;
- Exploring ways to develop international collaboration, dialogue and governance frameworks;
- Improved monitoring of GHG emissions and concentrations, e.g. with IG3IS / WMO

83. **Circular Carbon Economy**

Naif B. Alqahtani, King Abdulaziz City for Science and Technology (KACST) – Saudi Arabia

The poster presented the concept of the Circular Carbon Economy (CCE) which offers a new way of approaching climate goals and extends the concept of a circular economy (Reduce, Reuse, Recycle) by including Remove and focusing on carbon and energy flows.

The CCE can play an important role in climate stabilization, ensuring that technologies are available, mature, and cost-effective to help achieve climate goals at a reasonable cost.

- Reduce represents all of the carbon mitigation options that reduce the amount of carbon entering the atmosphere. Energy efficiency will reduce energy consumption and the associated carbon emissions. For example, the King Abdulaziz City for Science & Technology (KACST) is working on creating clean and efficient fuels by separating hydrogen from oxygen in water by electrolysis using solar power.
- Reuse refers to capturing and using carbon generated by industry or chemical processes to a feedstock for industry. The Saudi Arabian Basic Industries Corporation (SABIC) completed a project that converts CO_2 waste from one facility into products such as fertilizers and methanol. KACST aims to develop catalyst-based technology that can efficiently convert CO_2 to synthetic fuels and chemical commodities.
- Recycle represents the natural carbon cycle, in which natural sinks draw carbon from the atmosphere and then release it again through decomposition and combustion. The "Biological carbon sequestration in soils" project aims to sequester carbon through plant photosynthesis to be stored as soil organic carbon (SOC) – creating a climate change mitigation mechanism and improving the status of desert ecosystems.
- Removal represents the removal of carbon from the system. Captured carbon can be either converted to feedstock or removed by storing it geologically. Saudi Aramco is researching technologies for Carbon Capture, Utilisation, and Storage (CCUS) which capture CO_2 and sequester it in geological formations.

III. Summary of presentations and discussions at the World Adaptation Science Programme special event

Three Science for Adaptation Policy Briefs have been produced on: Adaptation decision-support tools and platforms; Transboundary climate risk and adaptation; and High-end climate change and adaptation

84. The World Adaptation Science Programme (WASP) special event introduced the first three WASP Science for Adaptation Policy Briefs (referred to above, see paragraph 26):

a). Adaptation decision-support tools and platforms;[53]

b). Transboundary climate risk and adaptation;[54]

c). High-end climate change and adaptation.[55]

85. The goal of the Science for Adaptation Policy Briefs is to produce an evidence base to understand emerging adaptation challenges and make effective decisions and policy. The briefs are targeted at researchers, policymakers, practitioners, and anyone involved in adaptation at the global scale at the science-policy interface.

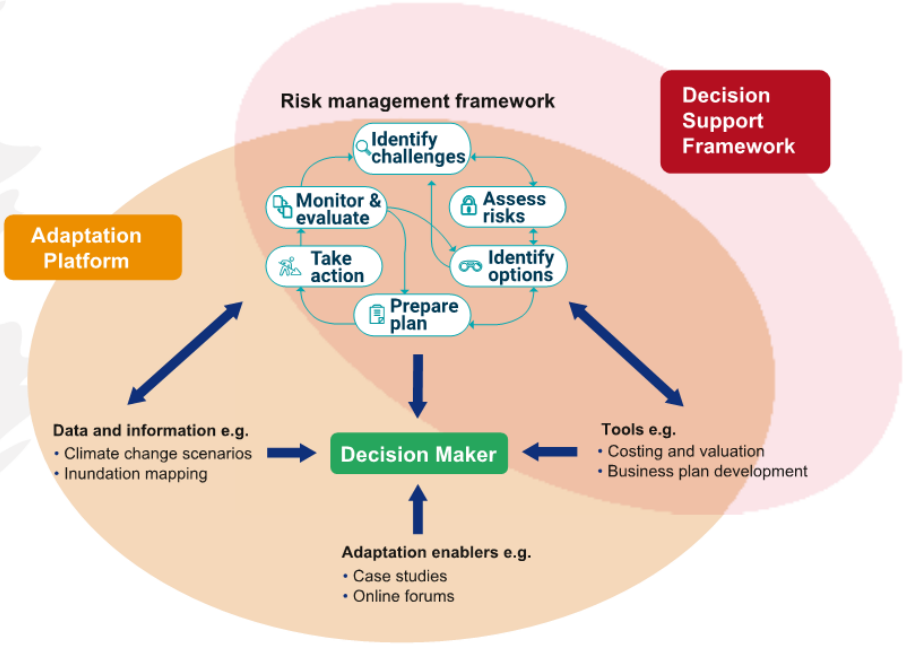
86. Ms. Palutikof chaired the special event which was opened by Ms. Johanna Nalau and Ms. Jean Palutikof. Presenters included members Mr. Roger Street, Mr. Magnus Benzie and Mr. Richard Betts. Mr. Richard Klein chaired a Q&A session following the presentations.

[53] Available at https://wedocs.unep.org/handle/20.500.11822/34435
[54] Available at https://wedocs.unep.org/handle/20.500.11822/34436
[55] Available at https://wedocs.unep.org/handle/20.500.11822/34437

1. Policy brief on Adaptation Decision-Support Tools and Platforms, presented by Mr. Roger Street.

87. Effective climate action requires support (knowledge, evidence, tools and advice) for sound adaptation decision making and to inform good practice. Over the past 3 decades there have been a number of adaptation platforms and decision support frameworks made available with different benefits and challenges. What is evident is that decision-makers must be at the centre of these platforms and frameworks (figure 19).

Figure 19
The overlap of adaptation platforms and decisions support frameworks



Source: Slide 2 of Mr. Street's presentation

88. From discussions with users and developers of adaptation decision support tools, the characteristics of a good tool can be described by its usefulness and usability. Usefulness indicates that it is relevant, comprehensive, reliable, and trusted. Usable indicates that it is accessible, authoritative, attractive, engaging, and inspires action. Therefore, effective tools require that developers have good knowledge and understanding of their targeted audience. What is useful and usable will change depending on the nature and needs of the users thus the level of their understanding and capacity will define the level of support they require. Finally, effective tools require codesign, co-production, and co-evaluation between developers and users.

89. There are both intrinsic and extrinsic challenges to designing successful decision report tools.

a). Intrinsic challenges include the potential for misalignment between the expectations of users and what developers can deliver. For example, engagement may be inappropriate, inadequate, or insufficient, or the user may expect an adaptation platform to provide instant solutions. Another intrinsic challenge is the limited understanding of the effectiveness of the tools and resources that are available in terms of the extent to which they are being used, by whom, for what purpose, and the extent to which they are useful.

b). Extrinsic challenges include a lack of sustained financial and human resources involved in maintaining tools. Funding and people for a project may disappear once the project is finished, leaving resources unsupported but still available online. There is also the need to retain the relevance of policy and practice. Policy is changing rapidly in most countries around the world as they realise the need for action, while practice is changing with new regulations and as users are developing or growing in capacity.

90. Existing and emerging research and innovation gaps include:

a). Decision support resources must be evaluated to determine the extent to which they fulfil the needs of adaptation practitioners. This provides a basis for updating and improving the existing

resources using evaluation mechanisms and metrics, including the support and understanding of co-evaluation.

b). Decision support resources must be objectively compared. Using different resources and tools will produce different recommendations for adaptation. Practitioners need guidance to make informed choices in the selection and application of decision support resources so that they may understand and reconcile differences. This will clarify the utility and robustness of different approaches and point to areas that need further development.

c). Business models need to be developed to sustain decision support systems in the long-term, both commercially and otherwise. Mr. Street emphasises that the long-term sustainability of these models is a process of continuous learning and improvement.

d). Mechanisms need to be developed that support the cross-fertilisation of ideas between developers and practitioners at the national and international levels.

2. Policy brief on Transboundary Climate Risk and Adaptation, presented by Mr. Magnus Benzie

91. An example of transboundary climate impact occurred in 2008 when forecasts of poor rice harvests in India led to a ban on exports of most kinds of rice. This triggered a chain reaction in the global rice market. Countries that were dependent on the imports of Indian rice either panic-bought rice at high prices, which further drove up the international price, or put export bans on their own rice stocks to insulate domestic markets. Global rice prices rose and countries, such as Senegal, were acutely affected. Rice prices doubled, resulting in street protests and affecting food insecurity, especially in urban households. The risk of such a transboundary event happening in the future increases as a result of climate change. The impacts of climate change that cross national borders The effects of adaptation actions that cascade across nation states

92. There are two important dimensions to transboundary climate risk:

a). The impacts of climate change that cross national borders (such as the example in the previous paragraph);

b). The effects of adaptation actions that cascade across nation states (adaptation actions in one state, such as banning exports of rice due to poor harvest) can impact risks and needs in other nation states.

93. This policy brief has four key messages:

a). **Adaptation is not (just) local or national** – it can also be regional or global, it requires scientific knowledge and cooperation at all scales, and should be recognized as delivering, in some cases, global public goods. Some adaptation plans do recognise transboundary issues, such as in the NAPs of LDC countries, where the need for regional collaboration is recognised, particularly in Africa. There are also some national assessments of transboundary climate risks, especially in European countries. In general, however, **there is a very low level of actual adaptation planning or uptake of transboundary climate risk messaging to address these transboundary climate risks**;

b). **Adaptation is not necessarily benign** – it can redistribute vulnerability and create or magnify risk for others, especially across borders. The key message is that **researchers currently know very little about how adaptation will have cross-border or systemic effects**;

c). **Adapting to transboundary climate risk falls between the remits of government departments and national jurisdictions and ends up being "no-one's job"** – analysis is needed to support solutions at various scales. **There is also low or no alignment between public adaptation strategies and private climate risk management plans and measures.**;

d). **Adaptation science should support the policy community to adopt a transboundary lens** to better manage the systemic nature of climate risk.

94. There are significant empirical challenges, complexities, and future uncertainty around cross-border risks, including the way in which globalisation will develop. There are also opportunities to meet the burgeoning demand for this kind of information by integrating transboundary climate risk into decision support tools (as discussed in the first policy brief above) and into guidance documents issued by the UNFCCC and others. WASP could play a strategic role in coordinating calls from the UNFCCC and engage with the IPCC and knowledge communities to develop new guidance on adaptation, communications, and NAPs.

95. Mr Benzie emphasized the interconnected nature of adaptation and that climate impacts do not stop at national borders: "The idea that countries, communities and companies can adapt in isolation is hard to accept in an interconnected world, but this is the implicit assumption behind much of mainstream adaptation research and practice. Responding to the global nature of the adaptation challenge will not be easy, but it could inject new momentum and spark new kinds of cooperation on adaptation – raising the bar to the benefit of all." **There is a large role for research to play in providing evidence and making the case for and supporting planners to integrate transboundary dimensions into future adaptation planning.**

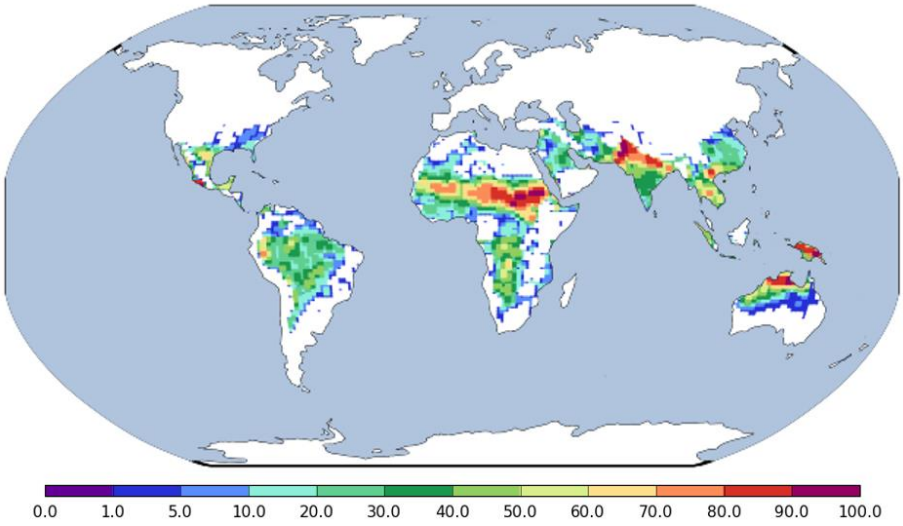
96. The research on transboundary risk was elaborated further in the poster session for theme 2 in the poster Managing transboundary climate risks to meet the global challenge of adaptation (see paragraph 232 below).

3. Policy brief on High-end Climate Change and Adaptation, presented by Mr. Richard Betts

97. **It is uncertain what degree of global warming will result from current or projected activities and policies. The future level of climate change depends on both the human impact on the climate system as well as on how the climate system responds to emissions generated by human activities**. The difference between emission scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) is quite large. RCP2.6 stabilises warming at around 1.5 to 2˚C, whilst RCP8.5 results in a very high level of warming – in many cases over 4˚C by the end of the century. There are also a wide range of differences between models within each scenario. For RCP2.6 for example, some models project stabilization well below the 1.5˚C temperature target, while some exceed 2˚C of warming. Current policies lead to an end of century global temperature rise that could be approximately between 2-4˚C. This policy brief assessed impacts at 4°C end of century temperature rise, which is a possible as an outcome from current global energy policies.

98. **In a 4˚ C world, the risk of human heat stress becomes a severe issue**. This can be quantified using the 'wet bulb globe temperature' metric, which combines the effect of temperature, humidity. and solar radiation. Humidity is particularly important as the body cannot be cooled by sweating in a wet heat. Figure 20 shows the percentage of summer days that exceed 32˚ C, at which outdoor exercise and outdoor working becomes dangerous to life. Across the tropics these levels of extreme heat stress would be seen for several weeks in the year in a 4˚C world, up to 3 months in areas such as the northern Indian subcontinent and parts of Africa and Australia. Different adaptation measures can be applied, including increasing indoor cooling facilities, but this still rules out outdoor work in those times. **It is uncertain how society will function under this level of heat stress.**

Figure 20
The percentage of summer days classified as Extreme Risk (maximum Wet Bulb Globe Temperature above 32°C) in a 4˚ C world



Source: Slide 3 of Mr. Bett's presentation; Laila Gohar, UK MetOffice

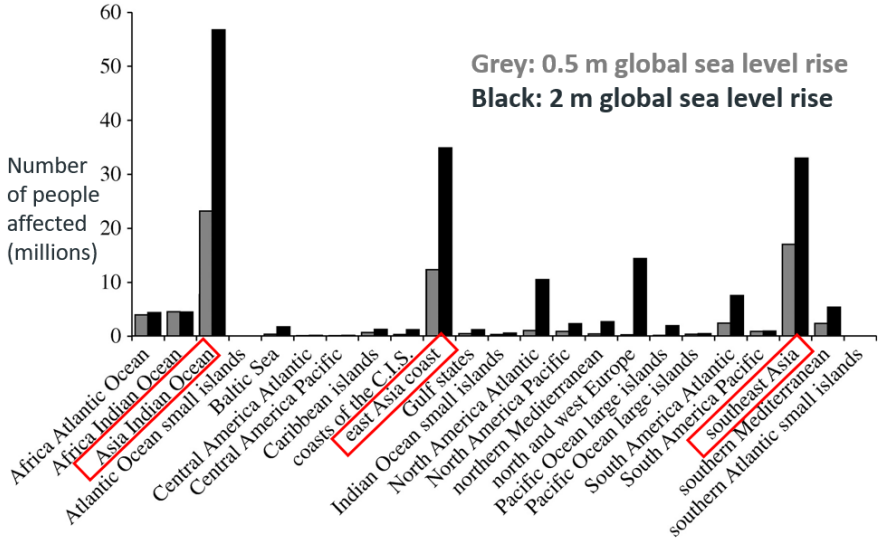
99. **The water cycle will continue to be affected in a 4˚ C world**. The combined average of different climate models results in a complex pattern with some areas of high uncertainty. In Southeast Asia for

example, some models show a decrease in drought stress, but others suggest an increase. It is not possible to exactly predict what will happen, and this increases the difficulty in planning long-term infrastructure.

100. **A 4˚ C world will also result in changes in river flooding events**. Although the change in average rainfall is highly uncertain, extreme rainfall due to hotter surface temperatures is projected with more certainty which could result in rainfall that is heavier although annual rainfall decreases. Most countries are projected to experience an increase in river flooding. It is important to avoid a lock-in of maladaptation in this issue. Infrastructure and homes that may be safe now may become more vulnerable, or part of a floodplain, in the longer term.

101. **The number of people affected by coastal flooding will also increase in a 4˚ C world**. The ocean has a relatively long lag in warming, making the timing of projections difficult. Figure 21 shows the number of people affected by potential sea level rise. Half a metre of global sea level rise will impact 10 - 20 million people in parts of the south, east, and southeast Asia. Tens of millions will be affected by a 2m global sea level rise, possible with 4˚ C of warming by 2100. Sea level rise raises the issue of the limits to transformational adaptation – with so many people affected, it may not be possible economically to build coastal defences to effectively protect all areas. Some areas may experience such frequent flooding that migration away from these areas becomes inevitable.

Figure 21
People affected by coastal flooding caused by high-end seal-level rise in a 4˚ C world under a projected 0.5m and 2m rise



Source: Slide 6 of Mr.Bett's presentation; Nicholls, R. et al. Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century. The Royal Society (2011) https://doi.org/10.1098/rsta.2010.0291

148. Mr Betts summarised that it is possible that 4˚ C of global warming will occur by 2100 with current global energy policies. This would lead to:

a). Severe global impacts and risks including frequent extreme human heat stress conditions in the Tropics, hundreds of millions of more people affected by coastal and river flooding, and more time under extreme drought conditions in many regions.

b). Sea level rise is projected to continue for at least several centuries even with low levels of global warming. Some adaptation to sea level rise could be possible, but there may be significant barriers.

c). Limits to adaptation mean that transformational changes may be needed, and large-scale migration may occur.

d). All of these impacts in a 4˚ C world would increase risks to human security.

4. Insights from the discussion session at the special event, chaired by Mr. Richard Klein

149. Insights discussed included:

a). Decision support tools must be created in consultation with users. These tools can be made robust and minimize uninformed decision making by incorporating any uncertainty in information. Enabling users to understand the limits of tools and the difference between tools that do and do not incorporate uncertainty is key.

b). Different regional and national platforms are coming together to make transboundary decisions. Demand should not always define the supply of research – transboundary climate risks exist regardless of whether there is regional demand. The research community must continue to support decisionmakers addressing these risks.

c). A starting point for enhancing transboundary decision making for transboundary risks is via existing regional organisations such as economic communities. Adaptation plans provide useful information to support this decision-making by determining whether the plans of one country may be beneficial or a risk to others.

d). There are important roles at the national and global scale to assess transboundary risk. This could be achieved through the global stocktake, by assessing the implementation of global adaptation measures, and by monitoring how systemic and transboundary risks are addressed.

IV. Summary of plenary presentations and discussions and posters on Theme 2: Factors for enhancing understanding to accelerate adaptation and mitigation

148. Presenters for Theme 2 included Mr Paul Durant, Head of End-use Sectors & Bioenergy, IRENA; Ms. Joyashree Roy, Professor, Asia Institute of Technology; Ms. Silvia Kreibiehl, Co-Head, Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance; Ms. Linda Anne Stevenson, Head of Knowledge Management and Scientific Affairs, Asia Pacific Network for Global Change; Mr. Daniel Morchain, Policy Advisor, IISD / NAP Global Network; Ms. Karen O'Brien, Professor, University of Oslo.

A. Proceedings

5. Understanding options and opportunities to support reaching net zero with renewable energy

149. Mr. Paul Durant presented on Reaching net zero with renewables: understanding the potential of renewable-based solutions for industry and transport in support of the 1.5˚C goal. He cited 2 IRENA publications of importance to this topic:

a). Global Renewables Outlook 2020;[56]

b). Reaching Zero with Renewables.[57]

Renewable energy options play a critical role in achieving net zero

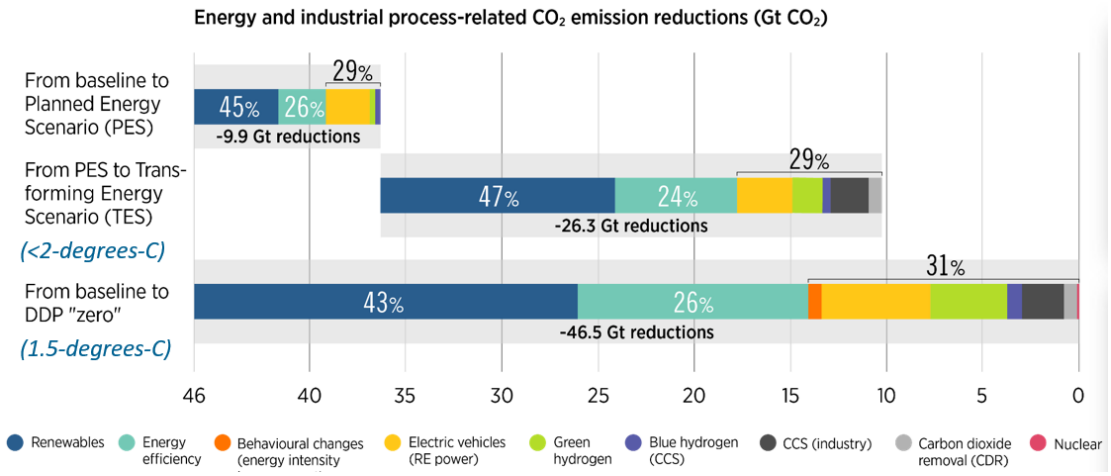
150. The Global Renewables Outlook roadmaps a pathway compatible with the Paris Agreement target of limiting global warming to well below 2˚ C and assesses options for achieving that goal (figure 22). As the policy context changes and a better understanding of the implications of 2˚ C of global warming is gained, a growing number of countries are supporting the more ambitious goal of limiting warming to 1.5˚ C. Achieving that goal will require reaching or getting very close to net zero global emissions by 2050, and momentum is building with pledges from, for example, China, Japan, and the Republic of Korea in 2020, building on pledges from over 30 countries and the European Union. There are also an increasing number of political commitments in place for achieving net zero, coming from states, sub-national regions, and companies.

151. All actors are at a different stage of planning mitigation strategies, but most are only starting to understand what commitment to net zero means in practice. **In most cases there is not much detail on the**

[56] Available at https://irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020
[57] Available at https://www.irena.org/publications/2020/Sep/Reaching-Zero-with-Renewables

plans or actions needed, but renewables will play a critical role. Direct electrification will be the dominant energy vector, but more information is needed to understand what is feasible with renewable fuels, particularly hydrogen and how to use that hydrogen to best effect, as well as the optimal use of biomass. IRENA established a Collaborative Framework on Green Hydrogen in June 2020, to foster dialogue between governments and private sector.

Figure 22
Roadmap for energy-related CO_2 emissions to 2050



The reductions and requirements for achieving a Planned Energy Scenario (top), Transforming Energy Scenario (middle) and Deeper Decarbonisation Perspective (DDP) "zero" (bottom). Source: Slide 3 of Mr. Durant's presentation; IRENA. Global Renewables Outlook: Energy transformation 2050. (2020)

Achieving net-zero, for a 2˚C pathway, would require an additional investment of USD 20 trillion by 2050

152. IRENA considered the investment implications of a Paris compatible pathway. It estimated that achieving net-zero, for a 2˚C pathway, would require an additional investment of USD 20 trillion by 2050 (2% GDP on average). Such a transition could also have large socio-economic gains. Of that total, over 80% needs to be invested in renewables, energy efficiency, end-use electrification, and power grids and flexibility.

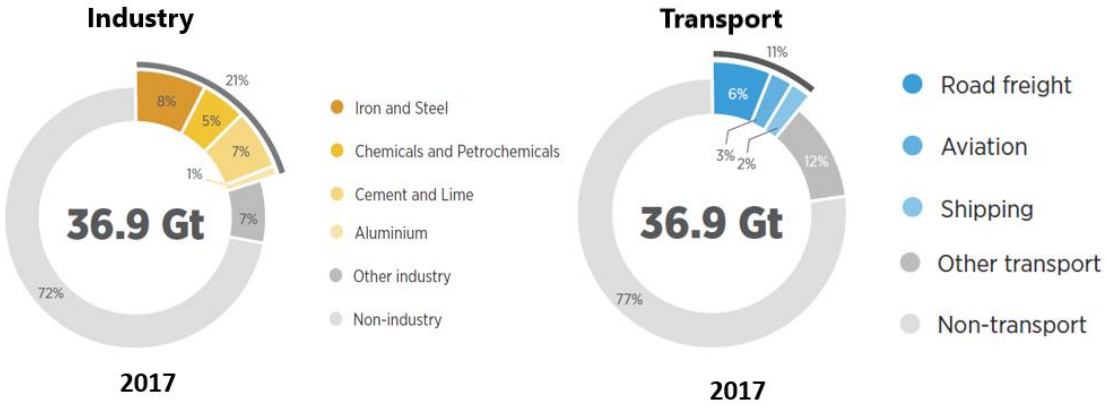
For power and personal transport – solutions are known and available. However, for 7 challenging industry and transport sectors (iron and steel, chemicals and petrochemicals, cement and lime, aluminium, road freight, aviation, shipping) – more information is needed to accelerate mitigation

153. With some sectors such as power and personal transport there is a reasonable understanding of the potential solutions (as detailed in the two reports). Delivering these solutions in a fast and just way will be challenging, but the pathways are clear. However, for some sectors, such as industry and transport the pathways are not yet clear. A particular challenge with industry is that it is not just emissions from energy use that need to be addressed but also the process emissions from several key industrial processes.

154. Total industrial emissions were 10.4 gigatonnes per year in 2017 – 28% of all energy and process emissions (figure 23). In IRENA's business as usual or planned policies pathway, emissions rise to 11.4 gigatonnes by 2050, accounting for 31% of all emissions. Three-quarters of those emissions are accounted for by 4 key industrial sectors – iron and steel, chemicals and petrochemicals, cement and lime, and aluminium.

155. Transport accounts for one quarter of the world's energy CO_2 emissions and 30% of final energy consumption. 92% of that comes from oil products, only 3% from biofuels, and a small amount from electricity. The pathway towards net zero emissions for passenger transport, road transport, and rail will be dominated by direct electrification. Challenging sectors such as heavy-duty long-distance road freight transport, shipping, and aviation, which together account for over half of transport emissions, cannot be as easily electrified.

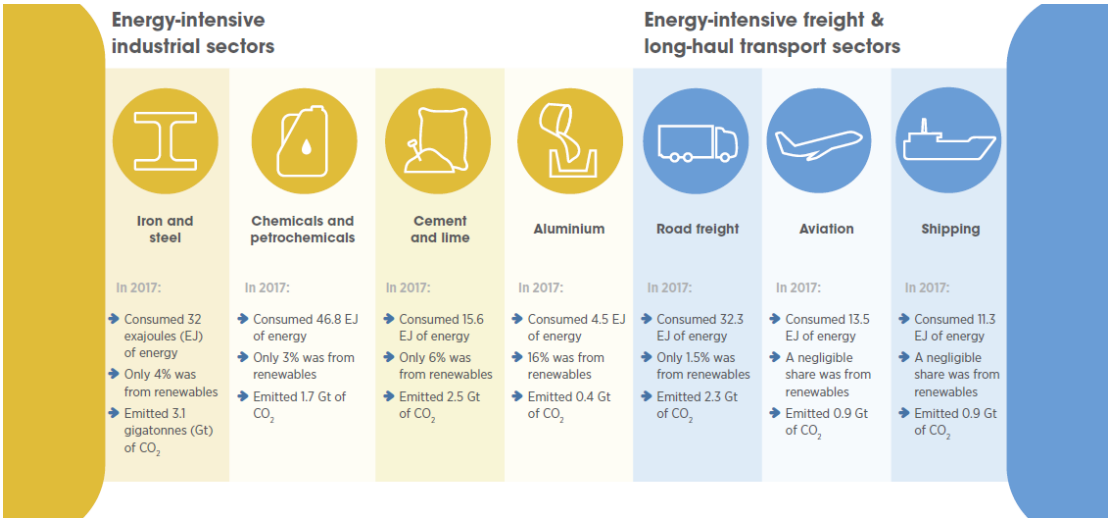
Figure 23
Proportions of CO_2 emissions from the industrial and transport sectors in 2017



(Left) From all industries, CO_2 emissions were 10.4 Gt/yr in 2017 – 28% of all energy & process emissions. Emissions of 11.4 GT/yr remain in 2050 under planned policies. (Right) Annual emissions in Transport increase by 0.1 GT/yr from 2017 to 2050 PES. Emissions of 8.6 GT/yr remain in 2050.Source: Slide 6 and 7 of Mr. Durant's presentation; IRENA. Reaching Zero with Renewables. (2020)

156. There are seven challenging sectors from industry and transport, that will emit an estimated 8.6 gigatonnes per year by 2050 under a business-as-usual planned energy scenario: iron and steel, chemicals and petrochemicals, cement and lime, aluminium, road freight, aviation, shipping (figure 24). These seven will account for 38% of energy and process emissions and 43% of final energy use by 2050 unless major policy changes are pursued. Progress in these sectors has been limited. The efficiency improvements that have occurred have been driven by economics rather than climate concerns, and the shares in renewables are low.

Figure 24
Seven challenging sectors for emission abatement



Source: Slide 8 of Mr. Durant's presentation; IRENA. Reaching Zero with Renewables. (2020)

157. However, two things have been changing in recent years which gives cause for optimism:

a). The growing political consensus on the need for action in all sectors and for all sectors to make deep carbon emission cuts;

b). The rapid decline in the cost of renewables over the last decade and the future potential for further cuts, reductions, and scaling up.

158. There are 5 initial reduction strategies that could collectively lead to net zero for these 7 sectors (figure 25):

a). Direct use of clean, predominantly renewable energy.

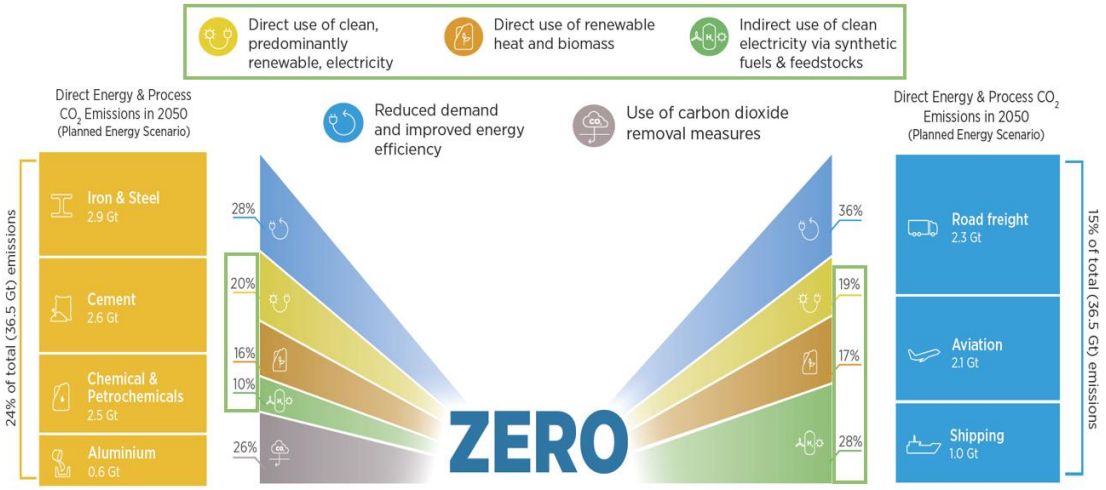
b). Direct use of renewable heat and biomass.

c). Indirect use of clean electricity via synthetic fuels and feedbacks.

d). Reduced demand and improved energy efficiency.

e). The use of carbon dioxide removal measures.

Figure 25
Five measures for reaching net zero in 2050 for the seven challenging sectors of transport and industry



The total emission for the challenging sectors of transport and industry in 2050 and the share of each option required to reach net-zero under the Planned Energy Scenario.

Source: Slide 9 of Mr. Durant's presentation; IRENA. Reaching Zero with Renewables. (2020)

159. Renewables account for about 54% of the economic emission abatement potential across these seven challenging sectors. There is potential for direct and indirect electrification, increases in efficiency, and circular economy concepts that reduce material consumption and can play a large role. For example, on the industry side, renewables can do much of the heavy lifting in this scenario due to falling cost, requiring less CCS than before, and making up 25 or 26% of the industry abatement.

160. The starting point of all these seven challenging sectors needs to be efficiency, but this will only help in the short-term. Materials efficiency is more critical as countries expand and, particularly as developing countries develop further, there is a growing demand for iron, steel, and cement. Efficiency in these sectors should not prevent growth but should mitigate the size of the growth without harming economic development. Changes in construction and maximizing the utilisation of scrap steel is the most efficient route there.

161. The goal of reaching net zero requires a different mindset than merely reducing emissions. A lot of discussion has been on partial emission reductions, small improvements in efficiency, or switching from natural coal to natural gas. These measures have a role to play and can help us in the short term, but if we are serious about reaching net-zero we must consider what solutions are consistent with a pathway to eventually reach net-zero emissions. Through that lens there are a relatively small number of options available in each sector:

a). Iron and steel is a politically important and complex sector. There is an over capacity of iron and steel production in the world, it is subject to trade disputes, and it is heavily impacted by the pandemic and the financial implications of that. It is a challenging sector on its own and particularly challenging to decarbonise. Current policies in iron and steel will account for 8% of global CO_2 emissions by 2050 - 2.9 gigatonnes. In the long term, there is a choice between using renewables or CCS. Both options are technically feasible but neither option is mature at this stage. Taking either of these routes requires many more demonstration projects between now and 2030 and a serious deployment of them afterwards, as well as several enabling actions taken this year.

b). Cement is subject to similar problems as steel, but the options are more complex. Emissions are innate to the process of cement production and reductions require reducing the demand for

conventional cement, eliminating energy emissions via renewables, and selectively applying CCS for the remaining emissions.

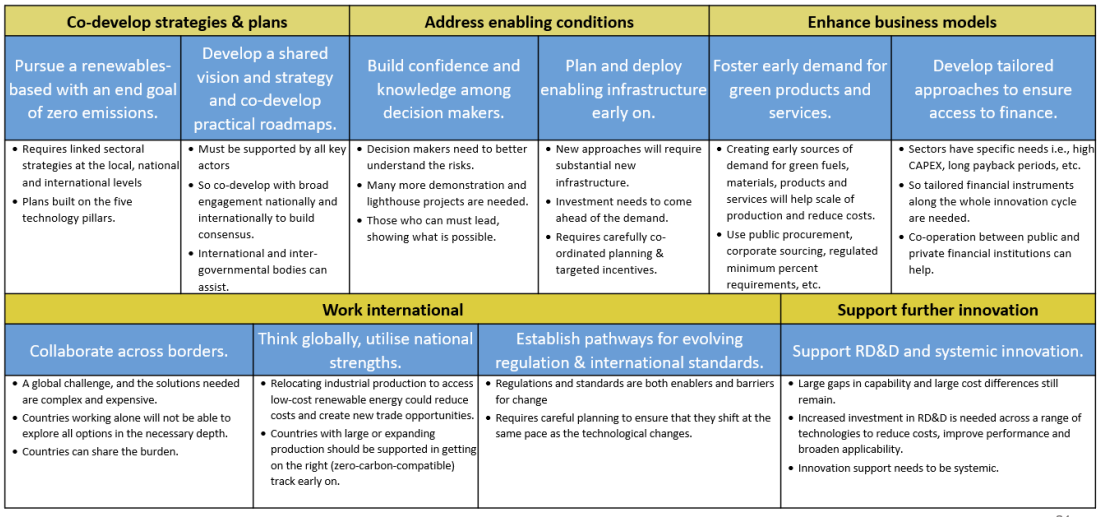
c). Chemicals and petrochemicals are even more complex as there are a wide variety of chemical products and chemical production routes. We can use biomass or synthetic hydrocarbons for feedstocks, we can capture both the process and waste emissions, and we can use renewable energy alongside that. There remains uncertainty as to the optimum route, but IRENA considers this pathway capable of delivering zero emissions if applied.

d). Options for the three transport sectors bear similarities to those for industry. The choice is between three fuels – electricity, hydrogen and its derivatives, or biofuels. The suitability of these depends in part on range requirements, natural national resources, access to traded resources including renewables, and the choices governments make in the infrastructure that they deploy. Any option produces complex trade-offs. For example, for road freight, it is thought that hydrogen will need to play a role. However, as battery technology has improved and battery costs have fallen electricity is playing a larger role. There are also complex trade-offs between the use of biofuels in aviation versus the use of biofuels in road freight, and some open questions about the role of hydrogen.

Priority actions to address knowledge gaps and enable mitigation across the 7 challenging industry and transport sectors have been identified

162. Mr Durant concluded with priorities for action for the 7 challenging sectors (figure 26). The starting point needs to be much clearer, and a shared understanding of vision and goals must be developed for each sector at a global, regional, and national level. Early action is needed to create the enabling conditions to position these sectors for the transition later, such as energy supply infrastructure, establishing trading conditions to allow international trade in green fuels, and standards and certification. Business models need to improve, substantial further innovation is needed, but crucially we need more international collaboration, as these are cross-border issues that cannot be solved in isolation.

Figure 26
Ten priorities IRENA recommends for action



Source: Slide 20 of Mr. Durant's presentation; IRENA. Reaching Zero with Renewables. (2020)

6. Research needs on consumption and behaviour for net zero

163. **Ms. Joyashree Roy** presented on understanding research on consumption and behaviour in decision making for net zero.

More social science research is needed on sustainable consumption to examine the diverse ways people aspire to live well whilst living within planetary limits in the context of reaching the goals of the Paris Agreement and other international agreements

164. Ms. Roy highlighted that international agreements, including the SDGs and the Paris Agreement, have underscored the importance of meeting human needs and aspirations within the limits of the planet

and the atmosphere. However, to date, there has been a paucity of research examining the diverse ways people aspire to live well and how we might meet international targets while recognizing how diverse values motivate and inform our visions for action.

165. Ms Roy outlined how sustainable consumption research can be divided into four broad approaches, as detailed in the report "Sustainable Living: Bridging the North-South Divide in Lifestyles and Consumption Debates:"[58]

a). Rational consumption approaches;

b). Social consumption approaches;

c). Degrowth approaches;

d). Just consumption and well living approaches.

166. The rational consumption approach focuses on the individual or business as the unit of analysis. It emphasizes the efficiency of resource used in production and consumption and the role of technological innovation, both of which require behaviour and supply change rather than reduced consumption. Examples of manifestations of this can be seen in incrementalism and in green-washing in the marketplace. For example, in India, industrial leadership has been advancing energy efficiency where an improvement in energy intensity has led to a reduction in energy consumption but has not affected activity growth. These industries are found to be motivated most by market-based incentives and government policies.

167. The social consumption approach incorporates more sociology, anthropology, and technology studies. Sustainable consumption literature focuses not only on understanding what individuals do but also on analysing why and how individuals, firms, policymakers, consumers, public opinion, and non-governmental actors all influence and in turn are influenced by social and political structures and the diffusion of technological innovation. This approach identifies how alternative service provision systems can change consumption practices and routines beyond technological innovation in the production system. However, even if consumption practices may change, the amount of consumption may not. An example of this is online vs in-store shopping where consumption practice has changed but the amount of consumption may not have.

168. The degrowth approach relies on multiple disciplines and cultural factors addressed through post-growth economics, ecological economics, the political economy, just consumption, and well living approaches. This approach tries to answer how consumption and the use of energy and material resources can be reduced while achieving human well-being within the constraints of a finite planet. This approach sets it apart from the previous two approaches. Degrowth is framed as collective political demand rather than individual consumer action and asks how interactions of individual agents and societal institutions can reduce consumption. The goal is to determine how the world's population can flourish more equitably.

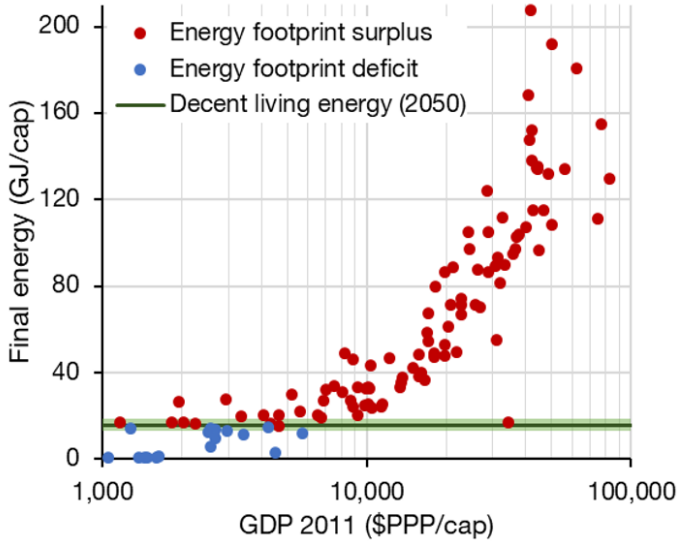
169. The just consumption approach is more attentive to systemic inequalities, ethical frameworks to assess needs and entitlements, and political participation. It includes considerations of intrinsic or self-transcendental values, such as concern for others, connections with nature, and collective rather than individual, materialistic, or extrinsic values based on reward and approval. Just consumption uses the feminist approach to understand the oppression of women and considers how new forms of slavery, marginalized groups, and informality are entwined in consumption and production, as well as consumption related debt. This approach raises questions on whether people in relatively free and affluent groups or governments should try to improve working conditions and wages of workers in far-off parts of the world where their consumed goods are produced.

170. Ms. Joy presented new research[59] on the just consumption approach which examined energy requirement per capita with the maintenance of decent living conditions (figure 27). Just consumption requires that trade-offs be considered on the societal scale related to this energy consumption. This approach contrasts with achieving sustainable consumption through technology-based transformations in which populations are viewed as users of technology, and citizens as consumers making rational choices. The just consumption literature emphasises global action and cooperation to bridge the North-South divide while respecting diverse values of well-being and sustainable living to advance sustainable consumption. The approach also highlights the need for nuanced understandings of intra-regional issues and differences in experiences of consumption.

[58] Available at https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-101718-033119

[59] See Millward-Hopkins, J et al. Providing decent living with minimum energy: A global scenario, Global Environmental Change. (2020) https://doi.org/10.1016/j.gloenvcha.2020.102168

Figure 27
Energy requirements to provide and maintain decent living conditions to all (green line), compared to countries' per capita energy demand against per capita GDP (red and blue dots).



Source: Slide 11 of Ms. Roy's presentation; Millward-Hopkins, J et al. Providing decent living with minimum energy: A global scenario, Global Environmental Change. (2020) https://doi.org/10.1016/j.gloenvcha.2020.102168

An increase in social science research on consumption and behaviour must be combined and coupled with scholarly works on sustainable living produced by local peoples, indigenous peoples, and those from the global South

171. Social science research on consumption and behaviour indicates that to move forward degrowth and just consumption research must be combined and coupled with scholarly works on sustainable living produced by local peoples, indigenous peoples, and those from the global South.

172. The just consumption approach provides a variety of solutions for low consumption societies while also achieving socially just and sustainable outcomes. Ms. Roy emphasised that individual actors in society must act consciously to advance sustainability while considering that nuanced visions of sustainable living informed by local values that are sensitive to long-term collective decision-making will support sustainable development and inspire social change.

173. The IPCC SR1.5 P1 pathway (see figure 13 above) demonstrated reaching 1.5ºC with no CCS aside from afforestation, and thus limiting any reliance on uncertain technologies. However, the P1 pathway highlighted tensions between weak sustainable consumption assumptions embedded in technological approaches, the efficient use of resources, and individual behaviour change. In fact, the more far-reaching transformations require reductions in the total level of energy consumption and production of goods and services while allowing for an increase in living standards where those standards are low.

A transdisciplinary research approach is needed to identify how demand can be managed to reduce consumption

174. Ms. Roy emphasised the importance of linking the discussion on the reduction of demand to the climate change debate.[60] The Global Energy Assessment included a chapter on "Lifestyles, Well-being, and Energy,"[61] where it was shown that, after a certain threshold, higher GDP does not lead to higher wellbeing. More recent literature further reinforces this finding.[62] It is therefore important that a transdisciplinary research approach is applied to identify how demand can be managed to reduce consumption. The

[60] See Roy, J & Pal, S. Lifestyles and climate change: link awaiting activation. Current Opinion in Environmental Sustainability. (2009) https://doi.org/10.1016/j.cosust.2009.10.009
[61] Available at https://iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter21_lifestyles_hires.pdf
[62] Available at https://www.inet.ox.ac.uk/publications/towards-demand-side-solutions-for-mitigating-climate-change/

discussion will continue in a stand-alone chapter in the IPCC Sixth Assessment Report[63] on behaviour and demand-side solutions for mitigation, which will describe how low energy demand pathways can be reached.

175. Ongoing gaps on consumption and behaviour research include:

a). Data on basic services demanded by people or cultural groups;

b). An understanding of culturally nuanced approaches to provide context-specific solutions;

c). An understanding of the macroeconomics effects of large-scale switches to sustainable lifestyles;

d). How alternative values might inform a redistribution of wealth;

e). How large reductions in consumption can be ethically embedded in everyday life;

f). The benefits of preventative actions, (such as investment in community healthcare and communal wellbeing rather than in individual well-being);

g). How these transformations go beyond regulations, policies, and governance.

176. Ms. Roy concludes by highlighting the fact that social science aspects of climate change research receive only a fraction of climate research funding.

7. Understanding research on climate finance for net zero

177. Ms Silvia Kreibiehl presented on understanding the research on climate finance in our existing and challenging macroeconomic environment focussing on the role of the financial sector in: i) transition and ii) considerations around indebtedness.

Misallocation of capital is limiting the financial sector's potential to be an enabler of the net zero transition

178. The Paris Agreement recognised the importance of aligning financial flows to climate targets, including from climate finance flows to financial flows and stock more broadly. Investors and finance have stepped up to the centre stage in the global policy conversation on climate change. The increased awareness of climate risk, in terms of both the physical impacts and the risk of a delayed and disorderly transition to a low-carbon economy, has given rise to multiple initiatives.

179. Nevertheless, misallocation of capital remains a key barrier that is limiting the financial sector's potential to enable the net zero transition. Climate-related financial risk appears to be massively underestimated by financial institutions, in markets and by public stakeholders, resulting in the current misallocation of capital. Research on decision-making under deep uncertainty has provided very strong evidence that high uncertainty is usually reflected in a limited number of scenarios by investors.

180. Major barriers for financial decision makers trying to integrate climate considerations in their investment processes (besides the observed inertia of the financial system) include:

a). High uncertainty with regard to path decisions;

b). Timing of transformative action;

c). Short to mid-term physical impacts of climate change.

Stranded assets and resources are expected to become a major economic burden for states and, therefore, also for taxpayers in the net zero transition

181. In addition, stranded assets and resources in the context of the transition toward a low emission economy are expected to become a major economic burden for states and therefore also to taxpayers. The effect will be felt both by the financial sector and at the government level.

182. Furthermore, the effects of unemployment, and regional fiscal effects, the negotiations and public support for compensations to offset negative effects of phasing out polluting technologies often remains interlinked and opaque. For this reason, phase-out deals tend to aim for partial compensation rather than receiving no relief at all. The energy sector in particular has a high level of investor protection against stronger climate action, as is illustrated by claims settled in favour of oil investors under the energy charter

[63] See https://www.ipcc.ch/assessment-report/ar6/

treaty and investor-state dispute settlements. This must be kept in mind when talking about stranded assets and when considering whether costs of stranded assets must be absorbed by investors or taxpayers.

A higher level of transparency and synergised approaches are needed for net zero transition

183. There is a strong focus on and high expectations for sustainable finance initiatives to have an impact on emissions reduction. However, there is no evidence that this is the case. There is high agreement among researchers focusing on the divestment movement that the awareness-raising effect is dominant, and it remains to be seen what effect this will have on emissions reductions. A higher level of transparency of pathways would help investors to define appropriate scenarios for their risk assessments. This is being called for by both governments and the international community who must work with the uncertainty of financial decision makers, and so more transparency can help to close the transition risk gaps.

Research shows that there is an extremely strong synergy resulting from a coherent financial sector and real economy regulations which can accelerate the transformation of the financial sector. Conversely, a reliance on the financial sector alone would most likely not result in substantial progress to net zero, in particular when the urgency of action is taken into account. It is suggested that rather than comparing the impact of financial sector regulation versus the real economy regulation, it is more important to find approaches that maximise synergies. This is currently not well-addressed in the current policy debate.

Understanding debt sustainability is vital for a just net zero transition

184. Ms Kreibiehl outlined new perspectives on debt sustainability, which must be considered in relation to the just transition and the ability of countries to mobilise funding for adaptation and mitigation. The situation before the COVID-19 pandemic was already alarming with increasing global debt levels. Approximately 50% of countries receiving funds from the International Development Association[64] were at high risk of, or already in, debt distress. 2018 marked a new peak in debt for low and middle-income countries amounting to roughly 51% of their GDP, and between 2010 and 2018 external debt payments as a percentage of government expenditure grew to 83% in these countries. The Covid-19 pandemic has intensified the existing economic inequality issues.

185. Climate change issues have been integrated into rating methodologies in recent years, which considers the effect of both long-term trends as well as short-term shocks caused by climate change. The IMF[65] considers a 20-year time horizon with separate forecasts for the first five years and the following period. The IMF uses a bottom-up approach, with individual country teams developing forecasts. However, this approach limits the transparency of the process, which has resulted in a continued overestimation of the future GDP and increases the vulnerability of highly indebted countries. Importantly, the incorporation of climate change considerations in rating methodologies has only negatively impacted country ratings.

186. If forecasts use forward looking adaptation investments, a positive impact is possible - where countries receive a better rating or are allowed higher indebtedness. However, this has not been realised yet or is simply over-compensated for by short-term vulnerability.

Research on climate change economics and considerations of traditional debt levels must consider new perspectives on and requirements of debt sustainability

187. One of the key challenges around debt sustainability is the difficulty in forecasting short and medium-term impact on a national level. Long-term impacts are the focus of the modelling community, but the short-term volatility of GDP driven by shocks is more difficult to analyse and requires country-specific deep-dives. IPCC scenario data is often not sufficient to perform such analysis, but these short-term impacts are crucial when considering debt sustainability.

188. It is important to not only consider future GDP and the amount of debt but also the appropriate use of capital market instruments and the investor mix. For example, in 2020 there was a large increase of capital market instruments and summary lending. The complexity of the rating methodologies underpins the complexity in finding sustainable debt levels. Artificial hurdles like the Maastricht Treaty[66] ceilings do not consider aspects like maturity profiles, GDP outlooks and sensitivities, investor mixes, and loan and debt terms.

189. The current discussion around debt suspension and debt relief in response to the current debt crisis are not linked to discussions around climate change related vulnerabilities and needs. This may be due to

[64] See http://ida.worldbank.org/
[65] See https://www.imf.org/en/Home
[66] Available at https://europa.eu/european-union/sites/europaeu/files/docs/body/treaty_on_european_union_en.pdf

policymakers feeling they should apply different policy instruments for different policy goals. However, holistic approaches have proven to be efficient in transforming systems.

190. Climate change is significantly increasing the vulnerability of countries facing high investment needs for mitigation and adaptation alongside the already higher financing costs of those countries. It is important that these countries are not burdened by weaker access to capital markets and vulnerability while they build the capacity to invest in adaptation and mitigation. Debt sustainability criteria needs to be defined in a way that avoids immediate next-debt stress.

191. More research is needed on the requirements of future solidarity structures, funding mixes, the role of capital markets, and debt or bond terms. Discussions on these must be combined with the research on climate change economics and considerations of traditional debt levels. This will be a crucial element to develop strategies to address the mismatch between funding and capital and be addressed in terms of the severe home bias challenges in markets.

8. Understanding contextual climate action needs at regional level in the Asia Pacific

192. Ms. Linda Anne Stevenson presented on some of APN's regional action on climate adaptation and mitigation in the Asia – Pacific region.

193. The pillars of APN's work focus on supporting regional research programmes in the global change sustainability space as well as supporting activities to strengthen the capability of scientists in the region to provide policy-relevant information. The APN[67] has **four strategic goals**:

a). Regional research collaboration in Asia and the Pacific.

b). Capacity building to participate in scientific research that supports decision-making.

c). Strengthening science-policy interactions.

d). Co-operating with other like-minded global change and sustainability organisations.

APN continues to support information exchange and capacity building in the Asia Pacific region to enhance understanding of science to support adaptation and mitigation

194. The results of the APN's fourth strategic phase shows the real benefits provided to APN member countries in the Asia-Pacific region. In the past 5-years APN has completed 119 projects, engaged with 11600 people and 1600 scientists of whom over 70% of those early-career scientists.

195. In collaboration with the Asian Institute of Technology, APN produced a special issue in the journal Environmental Research on Climate Change Impact, Vulnerability and Adaptation: Asian Perspective.[68] The journal provides the outputs from a symposium bringing together the leaders of 15 APN activities. It covers new climate change information, policy gaps, and lessons learned for the wider dissemination of information to practitioners and policymakers. The symposium and special issue provided the opportunity for researchers to network and collaborate as well as develop capacity to write and critique journal articles. This type of activity is critically important in the developing nations, and especially so for non-native English speakers.

196. As part of the special issue, a knowledge synthesis of climate change efforts in Asia (2013-2018)[69] suggested that there are 115 distinct and relevant projects in Southeast Asia, South Asia and Temperate East Asia, with the three thematic areas of highest frequency revealed by the synthesis were ecosystems; water; and impacts, adaptation and vulnerability. The details of the synthesis were provided in the APN poster *Climate Change Research in Asia: A knowledge synthesis of Asia-Pacific Network for Global Change Research (2013-2018)* (see paragraph 237 below).

[67] See https://www.apn-gcr.org/
[68] Available at https://www.sciencedirect.com/journal/environmental-research/special-issue/10KXCRMVJ96
[69] See Uchiyama et al. Climate change research in Asia: A knowledge synthesis of Asia-Pacific Network for Global Change Research (2013–2018), Environmental Research (2020) https://doi.org/10.1016/j.envres.2020.109635

Future activities should focus on generation of more products that are evidence-based and structured around frameworks to make them easily useable to inform policy

197. The synthesis report concluded that the APN must continue to produce publications of different formats to diversify pathways not only for supporting policy creation, but also to cater to other stakeholders and audiences and to utilise outputs of projects and activities.

198. The outcomes of the knowledge synthesis show the importance of increasing the relevance of APN projects with international climate change programmes (e.g. IPCC) to produce more products that are evidence-based and include highly practical solutions. These type of products are framework-oriented and thus, can easily inform policies. Learning from policy interactions, APN is in the position to provide a solutions framework or similar platform to obtain lessons learned from a significant number of contextualized and site-specific projects.

199. Ms. Stevenson highlighted 3 of the community-based adaptation APN projects building this important knowledge base and with it increasing resilience to climate change.

a). Reusing crop residue to enhance soil function and reduce emissions in climate adaptive agricultural waste management in India and Bhutan. While limited to local scales, this study has developed a place-based method framework and experimental design which can be used anywhere in the world to find out the most environmentally and production-wise effective crop residue management system. The study has attracted good peer focus and initiated a new paradigm in climate smart agriculture in the South Asian context

b). Capacity-building to enhance climate risk resilience through human security development in the Aurora province in the Philippines. This project administered an institutional capacity assessment in eight municipalities and provincial governments. Institutional capacity was measured using indicators representing access rights and entitlements, information flows, decision-making processes and application of new knowledge, capacity to respond and recover. Key results show that the process of preparing local climate change action plans is a major challenge for local governments and institutional capacity assessment reveals a strong correlation between expertise and position. One of the keys to institutional capacity building is therefore competency development among local government units as frontline agencies in climate change adaptation. This can only be realised by improving staffing and human resources, as well as gaining access to financial support and knowledge management systems.

c). Optimising climate change adaptation through enhanced community resilience in Vietnam and Cambodia. This study showed that simple assessment tools can identify changes in resilience, and that sustained resilience building requires community development. The assessment toolkit developed as part of this project can be readily used by Commune Councils as part of annual community (Commune) planning exercises and to mainstream climate change adaptation into development initiatives. Further work could be undertaken to develop aligned quantitative proxy indicators where sufficient financial resources exist to measure them (e.g. water quality as a measure of the quality of the natural environment, food security index as a measure of access to resources in times of crisis/stress).

9. Welcoming complexity in adaptation research, policy and action

200. Mr Daniel Morchain presented on the importance of welcoming complexity in adaptation research, policy and action.

Adaptation is complex and 'messy' and requires understanding of technical and human social processes exploring new ways of doing research, forming partnerships, engaging with stakeholders to achieve a meaningful change

201. He emphasised the importance of understanding that the act of adapting to climate change is both a complex and a messy process if it is intended to achieve a meaningful change. 'Complex' in this context refers to recognising that adaptation requires technical and a human social process and the need to explore new ways of doing research, forming partnerships, engaging with stakeholders, and actively addressing biases in the way that we work. These approaches may be 'messy', for example when collaborating across disciplines or measuring impacts to people intended to benefit from adaptation efforts, but these complex and messy processes will produce positive results.

202. A simple narrative is tempting but has important limitations. We must be careful that it does not mislead our efforts as researchers, policymakers, or practitioners. For example, the term 'Build Back Better' was originally associated with disaster risk reduction in the Sendai Framework[70]. In the context of disaster risk reduction, building back better makes good sense, but now it is being used everywhere. It has an appeal, but adaptation is a lot more complicated than building back after a hurricane or a drought.

203. The emphasis on building as the primary solution for adaptation must be challenged. For adaptation to be effective it must respond to less physical aspects like governance-related issues, justice and other invisible barriers. However well-intentioned building back better is, it can emphasise the wrong priorities.

204. Research and understanding of the ultimate objectives of adaptation policy should always welcome complexity. Adaptation is about building up, but also about removing what no longer works or has never worked, particularly for the most affected or disenfranchised groups.

The context of adaptation decision making informs what counts and doesn't count – and more emphasis must be given in research and decision making on social factors such as gender, equity, institutional context and the nature of transformation

205. Mr Morchain outlined the problematic context in adaptation research, policy, and practice:

a). Climate decisions spaces are largely male dominated. This is problematic from an equality and diversity perspective, but it also narrows the scope for climate change solutions by focusing on a limited group of disciplines – mostly natural sciences and engineering. The percentage of women to men at mid-career and experienced levels is small (for example of the experienced level professionals in global environmental science 19% are women and 81 % are men). Furthermore, 75% of heads of delegations of parties to international climate change negotiations are men.

b). The COVID-19 pandemic is already slowing down and possibly even starting to overturn progress made in inclusivity, particularly in science and research. There is evidence that women, especially mothers and those who are caring for elderly or ill family members submit fewer articles, work fewer hours, have less visibility in climate fora, and have lost productivity at work. Men's productivity has risen significantly. Racial and ethnic minority groups are similarly affected.

c). Adaptation and climate action are overly shy of transformative approaches. Consequently, they remain focused on incremental solutions and gradual change. There are higher risks associated with transformative solutions, especially where they are untested, experimental, or require radical shifts, but, while we must be aware of these risks, transformation must address adaptation needs. Aspects of transformation may not be easily visible, they may be hard to report on or measure such as governance, wellbeing, a sense of empowerment, or mental health so are not commonly worked on. Transformation for adaptation is sometimes misunderstood as only concerning technological breakthroughs, and this can undermine the importance of transforming the structures and the systems that do not currently deliver solutions for all. Research has found a causal relationship between increased political representation of women and more stringent climate policies that lead to reduced greenhouse gas emissions in their countries or regions. Gender equality and inclusivity in research and decision making is not just a rights issue, it also promotes more effective action and results.

d). Current institutional context has not opened up enough to make structures of power more flexible. For example, grey literature is not given as much weight as traditional research, researchers from the Global South have fewer opportunities, power dynamics between the natural and social sciences are unlevel, and English has an advantage over other languages.

206. The factors above directly affect and inform what or who does or does not count in adaptation. Both 'what' and 'who' are important but focussing on 'what' is easier. Adaptation as a social issue is not served unless we give prominence to these points that often are not considered.

As adaptation is complex and messy, so is adaptation research and research capacity building – it must be multidisciplinary and inclusive to make positive impacts on human lives

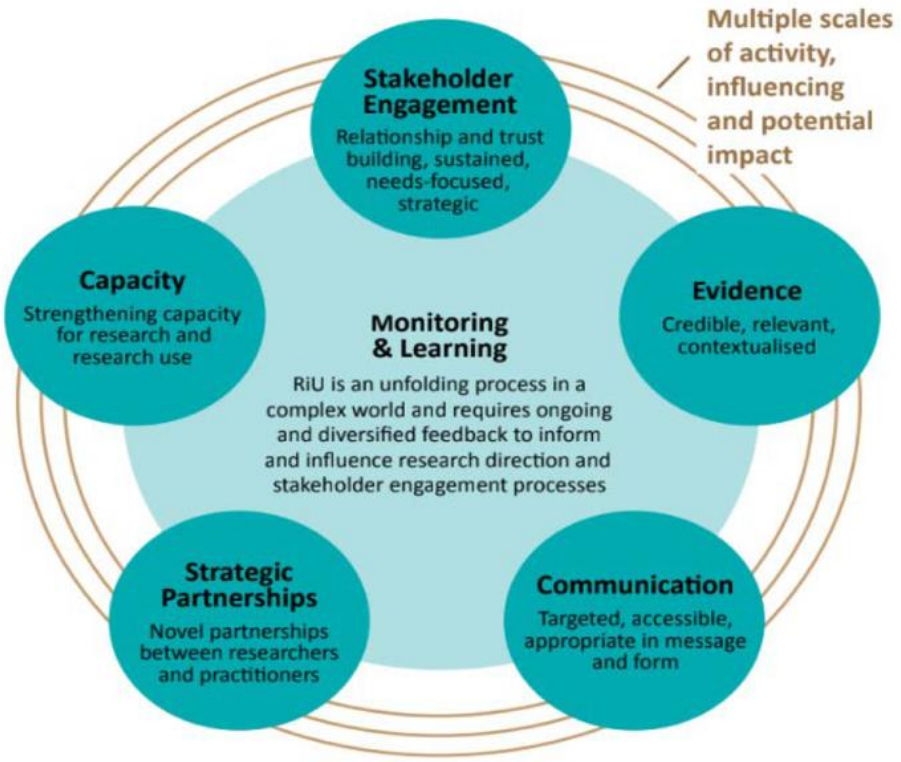
207. The Collaborative Adaptation Research Initiative in Africa and Asia[71] (CARIAA) programme outlines 5 key points to consider for researchers seeking to have an impact (figure 28): stakeholder engagement, evidence, communication, strategic partnerships and capacity.

[70] See https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030
[71] See https://www.cariaa.net/home-0

208. In regards to strengthening capacity, the UNFCCC PCCB[48], with a number of partners including the IISD and NAP Global Network[72] ran three regional Knowledge to Action Days in 2019 and 2020, one each in Latin America and the Caribbean and Asia Pacific, and one virtually in Africa. The details are outlined in the poster *Enhancing the capacity of researchers, policymakers and civil society to talk to one another and strengthen the climate science-policy-action interface: Capacity-building Knowledge to Action Days* (see paragraph 238 below)

209. The knowledge to action days helped participants understand the challenges and opportunities that researchers and policymakers are facing related to collaboration, find ways to identify capacity-building challenges, and ensure that capacity building is seen as a complex issue rather than something solved in a training session. As the understanding of the role of capacity-building is seen as a more complex process, the hierarchy of knowledge will be reduced, capacity building efforts will become multi-directional, and the solution space for adaptation becomes larger and more fertile**.**

Figure 28
5 key points to consider for researchers seeking to have an impact from the CARIAA programme



Source: Slide 12 of Mr. Morchain's presentation; Prakash, A. et al. Climate Change Adaptation Research for Impact CARIAA Working Paper #22. International Development Research Centre (2019)

210. Mr. Morchain concluded that adding complexity is beneficial even if research consortiums will have more disagreements as they become more heterogeneous, or if indicators for policy success are even harder to track as they incorporate improvements in quality of life. This is the next step in making the machinery of climate action fairer and more representative of the issues that it should be trying to address. Adding complexity will create a 'good mess' as it makes adaptation efforts are more meaningful and increases the likelihood that they will have meaningful impact on people's lives.

[72] See https://napglobalnetwork.org/

10. Understanding how to accelerate action on climate change: Engaging with the practical, political, and personal spheres of transformation

211. Ms. Karen O'Brien presented on engaging with the practical, political, and personal spheres of transformation to accelerate action on climate change. In this context, key questions are:

- How do we transform at the scope, scale, speed, and depth that is called for by climate science?
- How do we transform in an equitable, ethical, and sustainable manner?
- What is the relationship between individual change, collective change, and systems change?

Accelerating action on climate change needs strategies and the strategies are messy and more complex than building back better

212. These three questions are critical to meeting the challenges of the Paris Agreement. We must have strategies and the strategies must be more complex than building back better. The strategies will be messy and must be engaged with in a way that incorporates values that contribute to a thriving and sustainable planet such as integrity, equity, justice, and security. To design the right strategy, we must address the right problem.

213. A distinction can be made between two different types of change problems – technical and adaptive. Technical problems can be diagnosed and solved by applying or improving established knowledge, knowhow, and expertise. Adaptive challenges include technical dimensions, but also draw attention to mindsets, including individual and shared beliefs, values, and worldviews. This distinction is important when it comes to climate change because if we approach the 1.5˚ C target and adaptation as technical problems then we are bound to fail. We are approaching tipping points and history tells us that addressing adaptive challenges as only technical problems will fail to have a meaningful impact.

214. Adaptive challenges are not just about transforming the world, but also about shifting the way we think about transformation and adapting to the idea that we individually and collectively influence the future. Transformations are about significant, physical and or qualitative changes in form, structure, or meaning making. Transformations also unleash human potential to commit, care, and affect change for a better life. This deeper dimension motivates many people to work tirelessly for climate change action and an equitable and thriving planet.

The three spheres of transformation framework can be used to understand and activate transformation for sustainability and people and meet the Paris Agreement goals

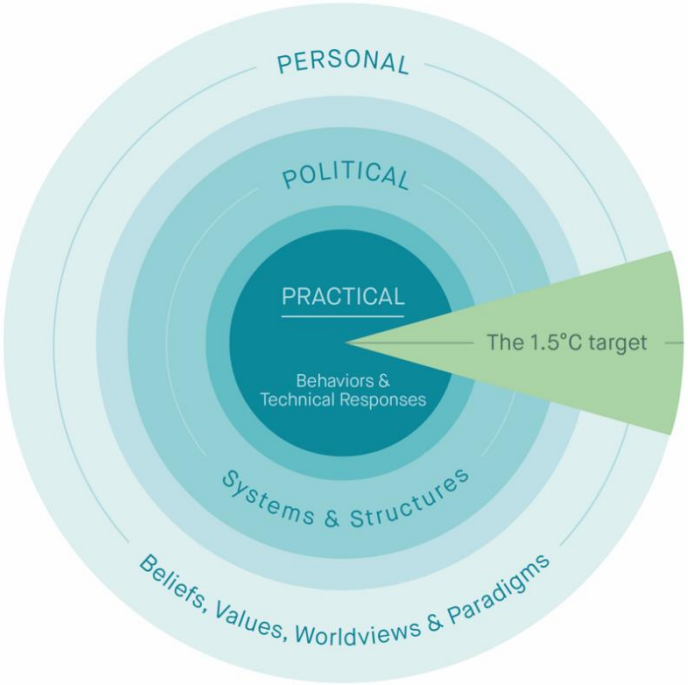
215. Ms. O'Brien created the three spheres of transformation framework (figure 29*)* that can be used to understand and activate transformation for sustainability. These interconnected spheres must each be engaged with in order to meet the 1.5˚ C target.

a). The Practical sphere is the core of the framework. It considers the behaviour and technical responses that are needed to meet climate goals. These have measurable indicators and also contribute to the SDG targets.

b). However, while there are many possible options to address climate change, we are not achieving our goals. To understand this, we must also consider the Political sphere. This sphere incorporates systems, structures, rules, norms, institutions, regulations and the ways society is individually and collectively organised. The issues can create conflicts and polarisation as well as social movements such as the degrowth movement and the divestment movement. The political sphere can therefore help or hinder transformation in the practical sphere.

c). Climate change agreements can get stuck in the political sphere for decades, often because we are not paying attention to the Personal sphere. This sphere considers individual beliefs, values, worldviews, and paradigms which influence how we see and relate to systems, who is included in our circle of care, and what values we prioritise for ourselves and others. In research, attention is given to shifting mindsets and dealing with those adaptive dimensions. We focus on changing other people's beliefs, values, and worldviews rather than thinking of our own beliefs and values and how to meet in the political sphere and connect with people who do not share our same priorities and interests. This is where power and politics affect the outcomes.

Figure 29
The three spheres of transformation, and the crosscutting 1.5˚ C target



Source: Slide 8 of Ms. O'Brien's presentation; O'Brien, K. Is the 1.5°C target possible? Exploring the three spheres of transformation. Current Opinion in Environmental Sustainability (2018) https://doi.org/10.1016/j.cosust.2018.04.010

216. Ms. O'Brien drew on the work by Donella Meadows to discuss leverage points for systems change.[73] Mapping the three spheres of transformation onto these leverage points, (figure 30).

d). The lowest leverage points often include the practical sphere issues such as the constants, parameters, numbers, buffers and the things we try to achieve but are often not moving the system rapidly or in the right direction. Much attention is focussed here.

e). The leverage points for the political sphere include feedback loops, information flows, the rules of the system, and the power to influence system structures. Many projects and initiatives also focus their attention here.

f). The goals of the system and the mindsets and paradigms from which systems arise are elements of the personal sphere, and these have power to influence everything else. The goals of the Paris Agreement and the SDGs demand that we must also look at mindsets and paradigms.

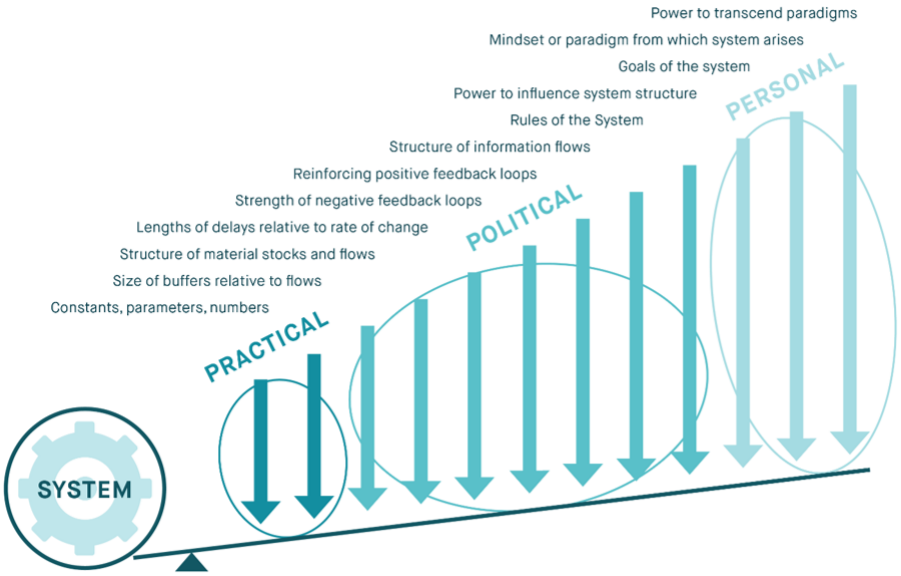
Increased understanding is needed in order for society to design for change and shift systems and structures that are not aligned or working with the goals that we have set out for ourselves such as under the Paris Agreement

217. To engage with paradigm shifts we must be willing to change the way that we think about how change happens, and how we relate to individual, collective change, and systems change. Ms. Monika Sharma[74] and others working on urban sustainability identify a fractal approach to scaling change. This involves generating self-similar patterns such as we see in nature, algebra, and geometry that replicate at all scales. Social fractals are based on values that apply to that whole system, so to work towards a sustainable world we need to have values embedded in equity, justice, dignity, and the elements of the 1948 Universal Declaration of Human Rights[75]. These are essential to a just and sustainable transformation and makes people engagement a very important aspect of change.

[73] See http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/
[74] The book "Radical Transformational Leadership: Strategic Action for Change Agents" is available in physical and digital formats.
[75] See https://www.un.org/en/universal-declaration-human-rights/

218. Recognising the outcomes of sustainability must go beyond considering how we can transform, but also consider the universal values that influence how we see, plan, and prioritise the system, and how we engage with it individually and in organisations in terms of engaging with transformations to sustainability.

Figure 30
Leverage point for systems change overlaid with the corresponding sphere



Source: Slide 13 of Ms. O'Brien's presentation; Meadows, D. H. Leverage points: Places to intervene in a system. (1999)

219. Our roles as individuals and collectives engaging with transformations in the three spheres can transcend scales. Ms. O'Brien referenced Mark McCaffrey's powers of ten framework[76], which considers the sweet spots in mitigation and adaptation initiatives where personal spheres of influence can make impacts. Looking beyond the technical and environmental aspects of problems and approaches allows us to unleash the power of people as not just the problems but solutions to climate change. Activating this based on people's values is one of the essential missing links in this complex and messy process of transformation. Until we do this, we underestimate our capacity for social change. This moves past concepts of 'us vs them' and 'right vs wrong' to consider how we act as agents of transformation and not just experts on transformation.

Discussion

220. **Do you think that we can reach net-zero using only renewable energy? Can renewables be used to such effect in the hard-to-abate sectors?**

Mr. Durant: Our analysis suggests that renewables can do most of the heavy lifting to decarbonise the economy. In general, the global renewable outlook concludes that about 90% of the energy supply in 2050 in our 2˚ C scenario can credibly come from renewables. That is not all of it, there will be a need for energy from other sources, and there is a need for CCS, which will have to be deployed in circumstances where other options are not viable, such as cement.

221. **To what extent might hydrogen become a game-changing renewable resource for industry and transport? What are the associated challenges and potentials?**

Mr Durant: Hydrogen is very important in the overall mix of solutions. There is some danger that it is touted as a panacea to all problems, but it is certainly very important. We must look at each individual sector to understand the potential there. In road transport its impact will be relatively small, but in shipping it will be quite significant, particularly in the form of ammonia. In aviation, the role of hydrogen is uncertain but we think that biofuels are likely to be the dominant carrier at least in the short to medium-term. However, companies like Airbus are building types of hydrogen planes. On the industry side, hydrogen is very important in steel, and I think that is the route that the

[76] Available at https://www.researchgate.net/publication/342368448_Powers_of_10_Seeking_'sweet_spots'_for_rapid_climate_and_sustainability_actions_between_individual_and_global_scales

sector should take. In other sectors less so, but it is potentially useful as a source of synthetic feedstocks for the chemical industry.

222. **How are CCS and CDR incorporated into the pathways IRENA describes?**

In the scenarios outlined in the reports a variety of carbon dioxide removal techniques are taken into account. There are two deep decarbonisation pathways consistent with 1.5˚ C. One is a net-zero pathway in which we assume a variety of carbon dioxide removal techniques in order to achieve net-zero emissions, and the other is a true zero pathway which is even more challenging. CCS has an essential role to play, and the debate is on how much CCS to plug some of the gaps left by renewables.

223. **Can you comment on difference between personal choice and an enabling environment in the context of consumption and behaviour?**

Ms. Roy: An individual cannot function in a vacuum. We work within a societal structure, within a political system, and with the different options provided to us with different incentive mechanisms and infrastructure. For example, I cannot switch off my air conditioner if I do not have other options to cool my house. These personal choices depend on the enabling conditions defined by policies, structures, and societal norms. A person as an individual can do very little depending on what enabling conditions are in place.

224. **Small islands are among the worst hit by climate change and the COVID-19 pandemic. With ever increasing climate damages, a debt relief for small islands as a critical enabler for adaptation and responses to loss and damages seems pressing. What is your perspective on that?**

Ms Kreibiehl: My personal perspective is that we need debt release and that we need to see more international public funding. There has been a focus on mobilising private investments which, if you compare current needs and the progress we have made in terms of climate funding, is not appropriate.

225. **Do IISD and the NAP Global Network work at the regional scale?**

The IISD and the NAP global network work across the world. We have programmes in Latin America and the Caribbean, in all regions of Africa, and also in Asia Pacific. We also work on adaptation at the local level, we support the NAP processes and the adaptation elements of NDCs. We are very interested in working on vertically integrated common multi-level governance and making sure that our work at the national level is linking with work at the subnational level.

226. **As climate change is still considered an inconvenient truth, how will you change the point of view of the ordinary people who are climate sceptics if the mass media tries to create the impression that there is no scientific consensus on climate change?**

Ms. O'Brien: This is a critical question. How do we shift those conversations? Going back to Meadows' leverage points, we see that information flows are very important in terms of seeing what matters to people, where they get their information, and how that helps us move from not just convincing people but also opening up deeper enquiry. At all levels when we look at what matters I think a lot of people are engaging from fear or from a little bit of paralysis. I think there is a potential to actually engage in different conversations and shift from 'you've got to believe in climate change' to 'how do you understand our relationship to nature and the environment in the future?'

227. **What are the critical strategies that are required using the three spheres framework?**

Ms. O'Brien: The critical strategies and questions are going to be very context-specific and we need to think about how to design for change and shift systems and structures that are not aligned or working with the goals that we have set out for ourselves. I want to emphasise the importance of the political sphere, shifting systems and structures, and how we engage with them.

228. **Do you foresee activities in practice as one way to create personal transformation, via community-based solutions for instance?**

Ms. O'Brien: I think the answer really does lie in practice, not just how do we engage but how we do so **now**. We can't just have these workshops and initiatives, we have to think about how we implement these projects and what the manner of transformation is beyond just the technical means. That is a challenge. This goes beyond 'being the change' to consider how to lead the change and rapidly shift what is not working, at all scales. Every fractal matters as it helps to create these new patterns and new structures.

229. **How can we shift power relations to empower the people who are most impacted and usually voiceless?**

Mr Morchain: This is one of the greatest challenges. I have been in projects where my own and others' perspectives have changed. One colleague working on a project completely shifted from believing that the solutions lie in academia alone to championing stakeholder engagement beyond just one-way consultation.

We can start by conducting more research that is multidisciplinary, understanding what changes are desired by using governments' and decision-makers' perspectives, and accepting the added complexity of working with new collaborators. This will be difficult, but it is necessary. Research funders and those funding these kinds of processes must realise that this is an important part of the work. Sometimes the problem is not that an institution does not want work like this, but that here is no budget.

We have a new project, for example, called 'Transformational National adaptation Plans' in South America and Latin America. One of the things we are doing differently is to bring members of the decision-making bodies of the governments of the countries that we are working in into project. They are there to ensure that whatever we are discussing as part of the research is as relevant as possible.

Ms. Roy: Social science research has shown that you need a critical mass to make a political movement. For example, with the vegan dietary shift there has been a critical mass that has driven that change. A change at the societal scale requires leadership and championing and the creation of a narrative to generate a critical mass that moves change forward and scales it up.

230. **What is the presenter's perspective on the importance of the COVID-19 recovery for transformational change to get the world on a 1.5˚ C pathway?**

Ms. Roy: The recovery package globally is now 12 trillion US dollars. Research finds that achieving the Paris Agreement requires only 1.4 trillion dollars. Governments have the money to take action to achieve Paris compatibility. However, if we look at the commitments made by the government on the 1.5 pathway, it shows that 0.08% has been invested out of what is required to achieve this compatibility. There is a very important political role to play for citizens and climate leaders this decade in making the point that we need to make a transformational change, and, when we have that money, how that change can be made climate compatible. The climate compatible pathway is also the recovery pathway. It is important that researchers themselves also make these compelling statements and cases.

B. Poster Session

231. Nine posters were presented on Theme 2: Factors for enhancing understanding to accelerate adaptation and mitigation and are summarized below. They can be viewed on the UNFCCC website for the twelfth meeting of the research dialogue[77] with accompanying audio commentary, or individually via a hyperlink in each title below. Presenters are listed below while the full list of authors is listed on each poster.

232. **Managing transboundary climate risks to meet the global challenge of adaptation**

Frida Lager, Katy Harris, and Magnus Benzie; Adaptation Without Borders / Stockholm Environment Institute

Climate change is a catalyst for cascading cross-border effects, from extreme weather events, slow onset changes and the unintended international effects of adaptation action. These transboundary climate risks are important to understanding our exposure and vulnerability to climate change.

The interdependent nature of our global system also means that our adaptation actions could have cascading consequences beyond where they are planned and implemented, potentially redistributing risk rather than reducing it outright.

For example:

- Rice production in Asia is sensitive to the effects of climate change. When India banned rice exports in 2007-2008 importers panic-bought and other exporters restricted their exports. This led

[77] See https://unfccc.int/topics/science/events-meetings/research-dialogue/twelfth-meeting-of-the-research-dialogue

to large price shocks in trade dependant countries such as Senegal, which experienced consequent social instability and food insecurity. Reducing levels of rice imports is one of the only steps Senegal can currently take to manage this transboundary risk, but due to Senegal's preference for imported rice, adaptation investment in Southeast Asia has the potential to pay double-dividends and increase the resilience of groups living continents apart.

- Sweden is vulnerable to transboundary climate risks via both the trade and people pathways. A study examined imports of Brazilian soy to Sweden and determines risk as a function of magnitude (depending on production location and shipping source) and likelihood (depending on how climate change affects production and transport).

A transboundary prospective raises important questions on the inclusivity of adaptation. If we only plan adaptation at a local or national scale can we be sure that we are building resilience for all? Transboundary climate risks may flow through various pathways including trade, biophysical, finance, and people. Decision makers will need to account for direct climate risks, as well as those originating beyond borders - the Transnational Climate Impact tool can assist decisionmakers to do so.

Adaptation is therefore a global challenge as:

- Climate impacts in one country may spill-over into others.
- Adaptation in one country may redistribute or increase vulnerability in others.
- Adaptation in one country may provide benefits to others.

The SEI Source Index assesses transboundary climate risks in agricultural commodity flows globally using global trade data combined with climate projections through the globally gridded crop model 'EPIC' across 2 climate emission scenarios and 3 time series. On analysing transboundary climate risks for six different commodities, results suggest that the distribution of risk differs substantially across crops, exporters, and importers, and that a limited number of major agricultural producers contribute disproportionately to transboundary climate risk in global food trade.

233. **The Hindu-Kush Himalaya (HKH) Call to Action: From science to coordinated regional adaptation**

Arun B. Shrestha, ICIMOD

The HKH area has global significance. The regions extends over 3,500 km in eight countries. It is the source of 10 major Asian rivers and is the largest reservoir of freshwater outside the two poles. The region is also affected by widespread poverty despite rich ecosystems and abundant natural resources. Due to its elevation, changes to the HKH cryosphere and biodiversity are a barometer of climate and environmental change across the world.

The 2019 report 'The HKH Assessment: Mountains, Climate Change, Sustainability and People', addressed the information gap indicated by the IPCC fourth assessment report of the region's mountains, environments and livelihoods, their status, and their future. The report underscored the significance of the HKH as a vital regional lifeline and global asset, and highlighted the threats to livelihoods, biodiversity, and sustainable development. This gave actionable information for the governments in the region.

The HKH Assessment highlighted the threats to this global asset and noted that even if the global 1.5˚ C target is achieved one-third of HKH glaciers will melt by the end of the century. Two thirds of glaciers will melt by 2100 under 5˚ C of warming.

The resolution of 'HKH Call to Action to sustain mountain environments and improve livelihoods in the Hindu Kush Himalaya' was signed at the the Ministerial Mountain Summit 2020. It strengthens regional cooperation, presents a unified voice for the HKH, assesses the feasibility of establishing a regional institutional mechanism and enhances the uptake of scientific evidence for improving policies in the region.

Country-specific actions and solutions were discussed and six urgent actions were identified, tailored to the local, national, and regional contexts, resulting in a roadmap for collective ownership by the eight countries and coordinated actions at multiple scales:

- Cooperate at all levels across the HKH region for sustainable and mutual benefits
- Take accelerated actions to achieve the SDGs and the nine mountain priorities
- Recognize and prioritize the uniqueness of the HKH mountain people
- Promote regional data and information sharing and science and knowledge cooperation
- Enhance ecosystem resilience and halt biodiversity loss and land degradation
- Take concerted climate action at all levels to keep global warming to 1.5°C by 2100

234. **Why equity matters in adaptation and mitigation actions on the ground? Insights from the Sahel**

Houria Djoudi, (CIFOR-ICRA), and Maria Brockhaus, (University of Helsinki)

A case study from northern Mali illustrated the shifting vulnerabilities of women caused by the effects of climate change.

Adaptive strategies are highly gendered. Migration is an important strategy for men but not for women. Women ranked migration as a factor increasing their vulnerability. Women are therefore affected by the climate related events, but also have to adapt to the migration of men.

For example, the drying-out of Lake Faguibine affected many people with sedentary agro-pastoral, transhumant pastoral, nomadic pastoral, and mixed livlihoods. Migration was an adaptation option available to men of each previous livlihood, but not to women, as it would further increase their vulnerability.

This vulnerability is increased by women's more limited access to and control over resources that will be exaggerated by climate change induced resource scarcity. Ignoring women's already high vulnerability, excluding them from decision-making, and not taking account of their specific perceptions and visions in national and local projects and plans will hinder a successful, transformative societal adaptation and limit women' adaptive capacity.

235. **Co-production for decision support in Future Climate for Africa**

Future Climate for Africa researchers

Future Climate for Africa (FCFA) is a climate research programme, implemented by five international research teams and supported by a coordination unit:

- AMMA-2050 (African Monsoon Multidisciplinary Analysis 2050)
- FRACTAL (Future Resilience for African Cities and Lands)
- IMPALA (Improving Model Processes for African Climate)
- HyCRISTAL (integrating hydro-climate science into policy decisions for climate-resilient infrastructureand livelihoods in East Africa)
- UMFULA (Uncertainty reduction in Models for Understanding Development Applications)
- CCKE (Coordination, Capacity development and Knowledge Exchange unit)

Knowledge co-production, an action research approach, was employed by FCA research teams to establish a common understanding of the region's decision-making contexts, key climate science concepts and scientific understanding on future climate. The poster highlights six case studies from this work

- Participatory approaches to co-produce climate information to support medium term planning – AMMA-2050, Senegal and Burkina Faso
- Co-producing Stories of the Future – FRACTAL, Southern Africa
- Learning lab, dialogues, and embedded researchers in cities – FRACTAL, Southern Africa
- FONERWA: Climate Risk Screening Tool – CCKE, Rwanda
- Co-producing climate information for medium-term planning in the water-energy-food nexus – UMFULA, Malawi
- Using video to initiate farmwr dialogue with local government – HyCRISTAL, Uganda

By applying coproduction approaches as illustrated through the 6 case studies, FCFA has supported incorporating this climate information into decision-making. To date, FCFA is on track to contribute to 17 policies and plans including the Uganda climate bill, the adaptation plans of Maputo (Mozambique) and Windhoek (Namibia), and National Adaptation Plans of Senegal and Tanzania.

236. **Interconnections of Earth-Human systems: Visualization and projection of future climate, ecosystem, water, energy, and food**

Tokuta Yokohata, National Institute for Environmental Studies (NIES), Japan

It is widely recognized that climate change affects multiple sectors in virtually every part of the world. Impacts on one sector may influence other sectors, which we call "interconnections of climate risks." The poster highlighted the interconnections of Earth-Human Systems as recognised through 3 different projects.

Visualizing the interconnections among climate risks

- A literature survey was carried out using the IPCC AR5 to identify 91 climate risks and 253 causal relationships among them and graphically drew the interconnected risk. The resulting diagrams have and can be used as a communication tool to inform climate risks.
- In dialogue events the diagrams are explained to the participants who then form small groups to to discuss global warming. The exercise increased the participants‘ understanding of the risks of climate change by discussing with researchers of climate sciences.

Projection of future ecosystem, water, energy and food by the MIROC INTEGrated land surface model

- Future changes in climate will affect the natural environment, human activity, and interactions between the two. This projection focussed on land use, because it affects and is affected by both natural and human systems.
- The model couples the state-of-the-art MIROC climate model to water resources, crop growth, land use, and land ecosystems. This can then illustrate interconnections between the changes in climate, crop yield, food and bioenergy cropland area, and ecosystems.

Projection of mountain permafrost and importance of adaptation in the Daisetsu Mountains, Japan.

- Permafrost exists in high mountains in Japan, and it is reported that the degradations of mountainous permafrost may cause adverse effects on current alpine ecosystems and increases the frequency of landslides.
- A future projection of mountainous permafrost was performed using a future surface air temperature with 1km resolution over Japan, and empirical relationships between surface air temperature and permafrost. This confirmed current estimations to be consistent with permafrost observation under the current climate.
- The projection showed that the permafrost will drastically decrease in the future climate scenarios. These results indicate the importance of adaptation measures, such as the future maintenance plans of trekking route, with the help of precise monitoring of ground surface using satellite observations.

237. **Climate Change Research in Asia: A knowledge synthesis of Asia-Pacific Network for Global Change Research (2013-2018)**

Christmas Uchiyama, Linda Anne Stevenson, and Effendi Tandoko; Asia Pacific Network for Global Change

Addressing climate challenges requires multi-layered approaches in cooperation with various stakeholders. Almost 25 years since its establishment, APN has been facilitating the research community to provide regional and grassroots results and solutions, while acting as a mechanism to encourage science-policy-stakeholder dialogue.

A review was undertaken to assess the relevance of APN projects to the IPCC and contribute to supporting science-policy processes. This review of knowledge products and lessons learned focused on APN projects completed in 2013-2018, with narrative discussion generally highlighting how regional research and capacity building assist in responding to the increasing urgency across climate change and the SDGs.

Overall, 115 distinct and relevant projects were identified mostly in Southeast Asia, South Asia and Temperate East Asia. Many of the projects involved community-based adaptation and mitigation surrounding issues on ecosystems and biodiversity, extreme weather events, water-food-energy nexus, sustainable waste management, and climate education.

In conclusion, although the projects reviewed were dominantly implemented at the local level, the report recognised:

- The importance of increasing the relevance of APN projects with international climate change programmes and agendas in order to produce more products that are evidence-based and include highly practical solutions.
- Knowledge products produced from projects are framework-oriented and can more easily inform policy and be replicated to disseminate key lessons learned.
- APN should continue to support programmes that produce publications of different formats to diversify pathways not only in supporting policy creation, but to cater to various audiences as well.

238. **Enhancing the capacity of researchers, policymakers and civil society to talk to one another and strengthen the climate science-policy-action interface: Capacity-building Knowledge to Action Days**

Marzena Chodor (PCCB), and Daniel Morchain (NAP Global Network / International Institute for Sustainable Development (IISD))

The Paris Committee on Capacity-building organized the Capacity-building Knowledge to Action (K2A) Days, a series of workshops at the regional level in Latin America and the Caribbean, Asia Pacific and Africa in 2019-2020. The PCCB also held a global workshop at COP last year.

The K2A Days brought together a diverse array of stakeholders, including national and local governments, universities, research organizations, and NGOs. Key features of the event series included:

- The diversity of participants and of the partnerships established.
- The gender and regional balance in all the events of the series.
- The focus on interactive discussions.
- A dynamic process of learning together and of digging deeper to try to understand the root of the problem and the ways forward.
- A focus on transferrable lessons and experiences across countries and regions, so that our learning can benefit stakeholders and adaptation processes in countries beyond those represented in this group.

Through the exchange of subnational and national-level experiences and knowledge, the K2A Days contributed to developing a better understanding of requirements for the engagement of universities and research institutions, policymakers, and civil society organizations to be more effective, constructive and frequent. These are pillars of a sound preparation and implementation of national adaptation plans and nationally determined contributions. Such processes almost always require capacity-building efforts in all directions and of all actors.

Key capacity needs identified by the event series for universities, research institutions, policymakers and civil society include:

- The need for increased efforts on effective knowledge management and multi-stakeholder networking.
- The importance of increasing funding, and transdisciplinary, collaborative research involving researcher and non-researcher parties, and its subsequent effect to make research more inclusive.
- The need for more creative, as well as better targeted, communication of scientific findings to ensure their effective and wider contribution to climate actions.
- The value that universities bring to the climate discussion and the need to balance universities' independence and their active engagement in socio-political contexts.

239. **Large-scale carbon dioxide removal: Are we ready? How can governance help?**

C2G initiative / Carnegie Council for Ethics in International Affairs

The IPCC's AR5 and SR1.5 reports made it clear that, in addition to transformational action to reduce emissions, large-scale carbon dioxide removal (CDR) will be necessary to limit warming to 1.5°C by balancing emissions and removals at mid-century and reach net-negative emissions thereafter which is reflected in the Paris Agreement.

Thinking and research on CDR are gaining traction, many actors are working to understand the role CDR could and should play in NDCs, particularly in the context of increased ambitions, such as the 2050 net-zero commitments by many Parties.

Governance (understood as interlocutors from across all sectors of society coming together in diverse processes to discuss, learn, share knowledge, and take decisions at multiple levels) is in the early stages: not only about the diverse options on offer, but how they might be governed, where, and by whom.

C2G's poses questions and identifies governance gaps to move the CDR research agenda forward:

- How might decision-makers determine whether, and if yes how to scale up various CDR options?
- How could CDR options impact not only climate goals, but all SDGs?

- What research needs to be done to fill those knowledge gaps? How to fund it?
- How could information be shared amongst global and national decision-makers?

Key governance gaps and challenges that exist for CDR at scale include:

- The rapid pace of CDR scale-up required to limit warming to 1.5°C.
- The responsibility and ethics of implementation.
- Incentives for CDR deployment.
- Access to information needed to monitor progress.
- Safeguards for sustainable development.
- Challenges for measuring, reporting and verifying CO_2 removals.
- Issues of storage: permanence, leakage and saturation.
- Planning for and monitoring the biophysical effects of deployment.
- Liability and redress.
- Public awareness.

Key actors need to be involved to address knowledge and governance gaps including governments at all levels, intergovernmental organisations, researchers, financial institutions, civil society, knowledge brokers and intermediaries, private sector.

C2G does not offer the answers, but can identify key gaps, drawing both on practical experience and a number of research papers undertaken with leading experts and academic collaborators.

240. **Risk and adaptation to climate change in RIOCC countries**

José Manuel Moreno Rodríguez and Clara Laguna-Defior, RIOCCADAPT Project, Department of Environmental Sciences, University of Castilla-La Mancha

The Iberoamerican Network of Climate Change Offices (RIOCC) is a governmental network on climate change of the Spanish and Portuguese speaking counties of the Americas and Iberian Peninsula.

Adaptation to climate change is a priority for all countries of the network and the RIOCC ADAPT report aimed to update knowledge on climate change risks and adaption in the region. The report addresses the major hazards, exposures, and vulnerabilities, with the consequent risks as well as the adaptation actions being implemented in the region in five main areas, and includes societal issues, terrestrial and marine ecosystems water, fishing and land resources, storms and hurricanes, floods and drought, slope instability and wildfires as climate related disasters and urban and rural settlements, coastal areas and tourism and human health.

Each of the sixteen chapters have been drafted by a lead author helped with several contributing authors and underwent two rounds of external review by experts and the governments. Each chapter summarizes the major issues concerning the main risks, adaptation actions. Examples of primary risks are described along with the main climate drivers, and the importance, urgency and extent of each risk within the region.

Adaptation actions are summarized and described in terms of climatic drivers, scale, type of action and status. Each chapter contains case studies related to its content of autonomous responses made by people of communities in response to past extreme events that could serve as examples of possible adaption activities to cope with the relevant driver. Each chapter attempts to identify the possible interactions of adaptation actions with other climate change, sustainable goals, and the Sendai framework for reducing disasters.

Finally, each chapter identified the main gaps and barriers as well as future needs on the topics of:

- Enhancing information and data availability on threats/vulnerability/exposure;
- Evaluation of the effectiveness of adaptation actions;
- Development of public policies;
- Socio-environmental aspects.
