Summary report on the eleventh meeting of the research dialogue Bonn, Germany, 20 June 2019

Note by the Chair of the SBSTA

18 November 2019

Overview

The eleventh meeting of the research dialogue (RD 11) was held in Bonn on 20 June 2019 in conjunction with the fiftieth session of the Subsidiary Body for Scientific and Technological Advice (SBSTA 50).[1]

The research dialogue continued to explore topics relevant to the Convention and Paris Agreement engaging with a wide range of experts from the research community, Parties and non-Party stakeholders.

The focus of the dialogue was on **science for transformation** to a world that can sustainably develop to meet the goals of the Paris Agreement. The aim of the dialogue was to hold a discussion at the science–policy interface to support adaptation and mitigation action under the Paris Agreement based on the best available science. To this end, the meeting centred on four themes:

1. Transformation of energy and other sectoral systems to achieve the purpose and long-term goals of the Paris Agreement;
2. Transformative adaptation and climate resilient development;
3. Changing levels of risk and the attribution of extreme climate events and impacts to climate change;
4. Role of the ocean in the climate system.

The dialogue consisted of a 1.5 hour poster session which covered all four themes. This was followed by a 3 hour dialogue session with presentations, Q&A and breakout groups, that explored the first two themes in more detail in panel discussions, with the third and fourth themes as cross-cutting elements.

This report provides an overview of RD 11.

Section I provides the background to the event.

Section II presents the proceedings.

The panel discussion presentations are summarized in section III of this report, with key messages provided for each presentation.

For the first time in the organization of the research dialogue, breakout groups provided additional focus on the guiding questions as identified in the RD 11 information note.[2] These guiding questions are listed in section IV along with the outcomes of the breakout group discussions, which were recorded by moderators and rapporteurs.

The poster session of the dialogue consisted of 51 posters and their key messages are provided in section V.

In last year's dialogue a theme that came out clearly was how to communicate at the science/policy interface. This year’s discussion went beyond that, to explore transformation, based on the best available science, to respond to the urgent need for rapid emission reduction and building resilience through adaptation. Included in the discussion was the importance of finding new ways of working in complex systems, bringing together a range of knowledge, treating scientific and traditional knowledge as equally important, and strengthening research support and needs for managing the transition to a sustainable, equitable future.

The information in section IV, as well as key messages identified in sections III and V, could be used as a basis to provide a summary of research topics to be addressed further by the scientific community in support of the UNFCCC process and its Paris Agreement.

[1] https://unfccc.int/node/196130.
[2] Provided in the information note by the SBSTA Chair, available at https://unfccc.int/sites/default/files/resource/RD11_InformationNote.pdf.

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I. Background

A. Mandate

1. The foundation for the research dialogue was given by the Conference of the Parties (COP) decision 9/CP.11 and further focus provided by conclusions of the Subsidiary Body for Scientific and Technological Advice (SBSTA) and COP decision 16/CP.17.[3]

2. At its forty-eighth 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 50 (17–27 June 2019), and beyond.[4]

3. In response to these mandates and submissions, the eleventh meeting of the research dialogue (RD 11) was convened on 20 June 2019 in Bonn, Germany, in conjunction SBSTA 50.[5] This report provides a summary.

4. The research dialogue also formed part of the basis for negotiations on research at SBSTA 50 under SBSTA Agenda item 6(b) on research and systematic observation. Conclusions are available online.[6]

B. Report

5. The SBSTA Chair has produced this summary report of RD 11 as requested by SBSTA 50.[7] The summary report as well as those from previous meetings are available online.[8]

C. Information note

6. In order to enable Parties to prepare for RD 11, the SBSTA Chair provided an information note in advance that provided background information on the approach, themes and goal for RD 11.

7. The focus of the dialogue was on **science for transformation** to a world that can meet both the goals of the Paris Agreement and the wider Sustainable Development Goals. The four themes for RD 11 were:

a) Transformation of energy and other sectoral systems to achieve the purpose and long-term goals of the Paris Agreement;

b) Transformative adaptation and climate resilient development;

c) Changing levels of risk and the attribution of extreme climate events and impacts to climate change;

d) Role of the ocean in the climate system.

II. Proceedings

8. RD11 took place on 20 June 2019, in conjunction with SBSTA 50 at the World Conference Centre Bonn (WCCB), Bonn, Germany.

9. The first session of the dialogue was a poster session including posters on all four themes, as well as cross-theme posters.

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[3] An overview of the mandates founding and guiding the research dialogue are available here: https://unfccc.int/topics/science/resources/research-background.

[4] Submissions were received from the Arab Republic of Egypt on behalf of the African Group of Negotiators (AGN), Bhutan on behalf of the Least Developed Countries (LDC), Belize on behalf of Alliance of Small Island Developing States (AOSIS), Japan, and Romania and the European Commission on behalf of the European Union and its member states. See http://www4.unfccc.int/sites/submissionportal/Pages/Home.aspx.

[5] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation.

[6] See SBSTA 50 report FCCC/SBSTA/2019/2 report, paragraphs 54–56 and 67–80.

[7] FCCC/SBSTA/2019/2, paragraph 79.

[8] See https://unfccc.int/topics/science/workstreams/research/research-dialogue.

10. The second session of the dialogue was a panel and discussion session chaired by the Chair of SBSTA, **Paul Watkinson** (France) and facilitated by **Sheila Ochugboju**, Specialist Facilitator. It consisted of a presentation from a representative of the World Climate Research Programme; then two panel discussions, on themes 1 and 2.

11. Panelists for theme 1 included **Elmar Kriegler**, Acting Head of Department - Transformation Pathways, Potsdam Institute for Climate Impact Research (PIK); **Jim Skea**, Co-Chair Working Group III, IPCC; **Marta Torres Gunfaus**, Senior Research Fellow, Climate and Energy, Institute for Sustainable Development and International Relations (IDDRI); **Riyong Kim**, Head of Programmes - Decision Metrics and Finance, Climate-KIC; **Carlos Fuller**, Belize; and **Harald Winkler**, South Africa.

12. Panellists for theme 2 included **Debra Roberts**, Co-Chair Working Group II, IPCC; **Hindou Oumarou Ibrahim**, Congo Basin regional representative, Indigenous Peoples of Africa Co-ordinating Committee (IPACC); **Candice Pedersen**, Ikaarvik, SIKU team of the Arctic Eider Society, and Inuit Circumpolar Council; **Tom Mitchell**, Chief Strategy Officer, Climate-KIC; **Tomohito Yamada**, Associate Professor, Faculty of Engineering, Hokkaido University, Japan; **Paulina Aldunce**, Department of Environmental Sciences and Natural Resources, University of Chile presented on science and transformative adaptation in the context of Chile.

13. Following the panels, there was the opportunity for breakout groups, moderated by an expert from the panel or poster session, on the guiding questions provided in the information note.

14. All presentations and posters are available online.[9] An audio Skype broadcast of the dialogue is also available.[10]

III. Summary of the dialogue

A. Opening presentation

15. **Ms. Boram Lee,** WCRP, opened the session with a presentation on the World Climate Research Programme titled Climate Science for Society.[11]

Key messages

- Continuous support for fundamental climate research, and enabling infrastructure, is essential to link science to action
    - Consistent support for critical work e.g. Coupled Model Intercomparison Project (CMIP);
    - Co-commitment and investment across nations, disciplines and societal sectors;
    - Embracing diversity, demanding equality, and building capacity for the future.
- Resilient society and sustainable future require collaborative efforts with multi-sectoral actors in all regions of the globe
    - Whole value chain for Research – Services – Decisions – Benefits;
    - Co-production of knowledge, co-design of solutions;
    - Connecting global to local scales for adaptation.

16. Ms. Lee expressed the importance of the dialogue during the poster session and highlighted that the purpose of her presentation was to connect seemingly unrelated issues and outline questions raised related to themes in the research dialogue that can support the Paris Agreement.

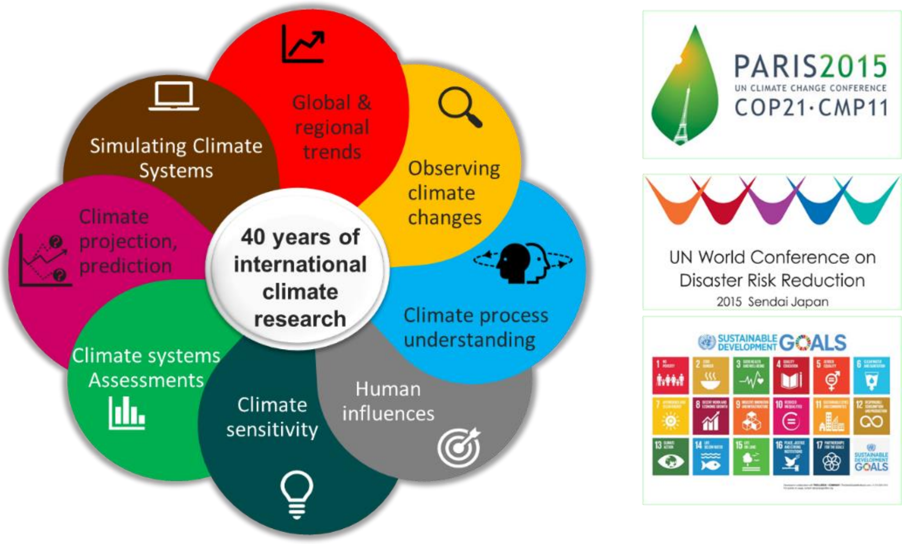
[9] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-11.

[10] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-11.

[11] See https://unfccc.int/sites/default/files/resource/0.Lee_WCRP_overview.pdf and audio broadcast 0:09:23.

17. The presentation also celebrated the **40 years of major achievements by the WCRP** (figure 1). This research work has formed the foundation to attain and support multilateral agreements including the Paris Agreement, Sendai Framework on disaster risk reduction and the sustainable development goals.

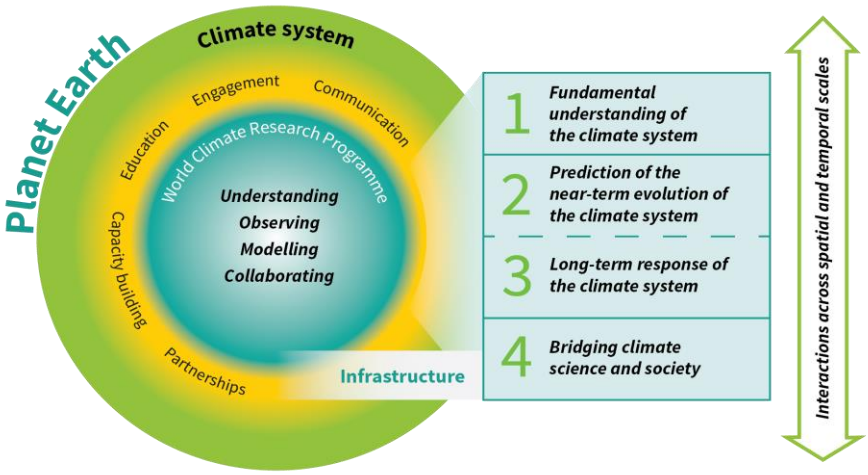
Figure 1
WCRP major achievements in 40 years of international climate research



Source: Slide 2 of presentation by Ms. Boram Lee.

18. The WCRP launched a new strategy in 2019, the **WCRP Strategic Plan 2019–2028**, "toward a more resilient present and sustainable future for humankind"[12]. It highlights how the WCRP and global research community will continue to work together, through **four overarching objectives**, to improve standards, observations and the modelling of the climate system (see Figure **Error! Reference source not found.**2).

Figure 2
The WCRP's new strategy "toward a more resilient present and sustainable future for humankind", illustrating the means and methods used to achieve their overarching objectives



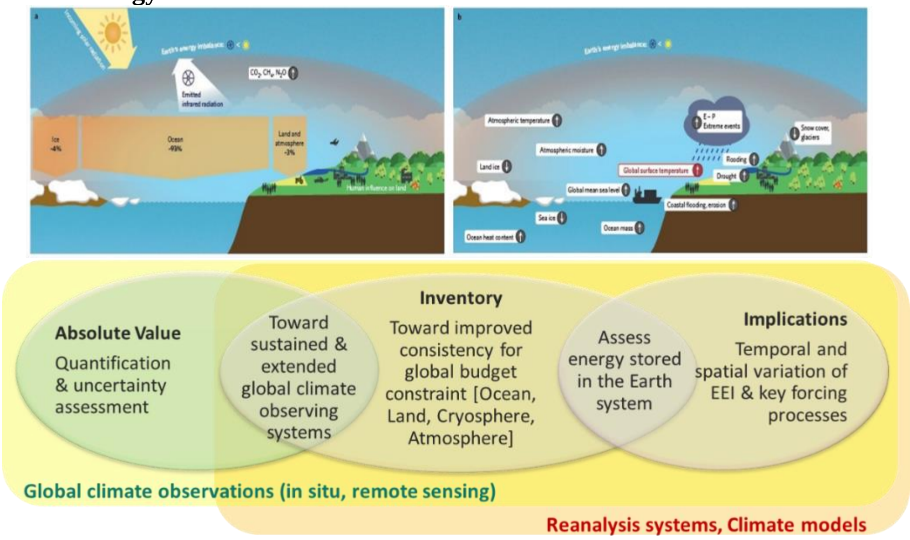
Source: Slide 3 of presentation by Ms. Boram Lee.

19. In regards to the Paris Agreement, WCRP goals are formulated based on a need to understand, quantify and predict or project reservoirs and flows of carbon, water, heat and energy globally. Fundamental questions are: Where does the carbon go? Where does the energy go? **Closing the energy, water and carbon budgets is essential to observe, assess and stimulate multi-scalar climate research globally and regionally**.

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

20. To understand how **anthropogenic influence has caused an energy imbalance**, it is first essential to quantify climate indicators such as air temperature, sea level rise and sea ice extent, as well as changes in precipitation and water variability. Finding the absolute values of these indicators, while accounting for uncertainty, is key to understanding their direction of change. This allows greater understanding of global and regional energy inventories which are required to project and predict the implications of temporal and spatial variation of the energy imbalance and to explain key processes. Once this is known, an observation system allowing analysis can be established, in which climate models play a key role (Figure 3).

Figure 3
The processes and values measured by the WCRP to understand how anthropogenic influence has caused the energy imbalance



Source: Slide 5 of presentation by Ms. Boram Lee.
Closing the energy, water and carbon budgets within the Earth system is integral to observing, assessing and simulating climate change and variability, regionally and globally.

21. When considering decarbonisation and transformative energy, **research on the effect of CO_2 removal and solar radiation management is critical for identifying promising approaches and avoiding unintended consequences**. It is not only important to develop new technology, but while doing so to also understand both climate system responses and consequences, which both have implications for sustainable development.

22. Fundamental science is also needed for the generation and delivery of decision-relevant information and knowledge on the state of the global climate, and the assessment and implementation of global climate ambition.

23. When considering climate resilience and the societal consequences of action, **the information on the current and future state of the climate used to inform decisions must be salient, credible, and relevant to the required timescale and spatial range**. This information is used to determine the processes responsible for the existence of regional climate hotspots and the potential for crossing thresholds and manifesting surprises, which then allows us to translate data on extreme events into risks. It is therefore necessary to employ a systematic approach when considering compound events. This allows a holistic approach to improving resilience, where the long-term view and present decision making must be considered together.

24. One issue in decision making is the **scale of the data used to provide input**. There exists various climate information and products that, while sophisticated and refined, are specific to certain uses. As decision making in different sectors and for different purposes also varies, the choice of climate information and products used to inform decision making must be carefully considered.

25. Creating resilient societies and sustainable futures requires **global collaboration with multi-sectoral actors**. The whole value-chain from research through services and decisions to benefits must be considered. Effort can not only be made by researchers, decision-makers and practitioners of one sector. Solutions must be **co-produced by different sectors globally**. As well as this, the **global scale must connect to the local scale** in order to effect adaptation and other climate actions**. Knowledge of the certainties and uncertainties at each scale is required to improve precision** in all approaches to implementation and associated development.

26. WCRP's new strategic plan (figure 2) identifies the essential infrastructure needed for implementation. This includes:

- **A hierarchy of simulation tools**. New technologies must be put into context with each other to allow the creation of a more effective and innovative operational architecture.
- **Sustained observation and reference datasets**. Quality control and sustained climate observation is critical for further development and improvement of our understanding of the climate system. Well-coordinated field and space based programmes should be continuously funded and supported. All of these efforts must take a multivariate and multi-scale approach.
- **Open access data and efficient data management**. Furthermore, this data must be interoperable, to be able to talk and apply to each other, especially data on societal climate resilience.
- **High end computing and data management**. Exa-scale computing and cloud-based systems are already being applied to new climate research and applications. The use of Big data and other computational advances supports effort to improve simulation projection and production.

27. Ms. Lee called for **continuous support for fundamental climate research**, and its enabling infrastructure, to make the essential link between science and action. This includes consistent support for critical work, such as CMIP; international co-commitment and investment across disciplines and societal sectors; and embracing diversity, demanding equality and building capacity for the future.

B. Panel discussion 1: Transformation of energy and other sectoral systems to achieve the purpose and long-term goals of the Paris Agreement

28. **Mr. Elmar Kriegler**, PIK, gave the first presentation on this panel, responding to guiding question: what are the key challenges and approaches to achieve the transformation of energy and other systems to hold global warming to well below 2 °C and pursue efforts to limit it to 1.5 °C?[13]

Key messages

- Emission developments over the next decade until 2030 are key to keep the goal of limiting warming to 1.5°C in reach.
- Technology pathways for reaching global carbon neutrality by 2050 exist and the full range of options must be used as identified in SR1.5.
- Transformation challenges include coordination, consideration of inequality, behavioural changes, entry points for enhancing action and shifting investments.
- Priority research topics include: better integration of mitigation and climate impact pathways; sustainable development implications to explore synergies with other SDGs and entry points to deep emissions reductions at national level.
- Technological innovations needed include: flexible energy systems; carbon-neutral synthetic and biofuels; enhanced emissions reduction and carbon dioxide removal options of sustainable land use management; and a variety of CDR and associated costs and implications.
- Innovations in social sciences can help achieve and manage the necessary social, economic and cultural changes.

29. Mr. Kriegler identified that transformation occurs in five steps:

- **Characterising the scope of the challenge**: Pursuing efforts to limit warming to 1.5 °C above pre-industrial levels and hold it well below 2 °C.
- **Getting started**: Reducing emissions, exploiting opportunities, overcoming barriers and linking transformation with other goals, such as the SDGs.

[13] See https://unfccc.int/sites/default/files/resource/1.1kriegler_research_dialogue_v20190620.pdf and audio broadcast 0:024:00.

- **Getting coordinated**: a massive challenge for societies inter and intra-nationally that requires the coordination of various societal actors including, governments, and civil society. Single-sector strategies will be ineffective and international coordination is required to ensure alignment with the Paris Agreement.
- **Scaling up**: Innovation to address decarbonisation bottle-necks. Motivating the investment of the trillions required to implement low carbon measures is a major challenge. In the finance sector, some risk processes such as financial risk disclosures and the network created by some central banks to 'green' the financial sector operation is actively enabling support and facilitating this investment.
- **Taking everybody along**. There must be a fair transition to new energy and land use. This may require compensation of losses, new perspectives offered to those undergoing transition, and finding synergies with multiple goals.

30. Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limit global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for the emissions and several other pathway characteristics.

31. Mr. Kriegler showed the scenario P3, identified in the IPCC SR1.5 (figure 4a) created using input from many studies, and the **robust messages** that emerged (figure 4b):

- Redirect investment away from fossil fuels to low carbon, more efficient solutions.
- Power sector decarbonisation is critical for organizing emission reductions. The end users of power are electrified (as opposed to receiving power from fossil fuels) and emissions are reduced while efficiency is improved. The scope of challenge on the supply side is therefore not so large. It is also necessary to prevent further deforestation in the land use sector.
- Carbon neutrality is reached around 2050 in 1.5 °C strategies. Societies must have achieved zero-carbon electricity and electrified end uses. Challenges remain in the form of end uses that cannot be electrified such as freight transportation, heavy industry, and aviation. Low carbon fuels are required to address those bottlenecks, and changes in AFOLU practices, among other methods, must be used to remove atmospheric carbon.
- On longer timescales, net negative CO_2 emission must be achieved by further removal to compensate for residual long lived emissions and prevent temperature increase above two degrees.

32. Mr. Kriegler identified that researchers face the challenge of coordination of coherent communication across research communities. For example, this is reflected in the structure of IPCC, which has 3 research groups reflected in the 3 working groups. In order to coordinate and provide consistent and coherent research results across dimensions, researchers use scenarios to link research work.

33. Scenarios with different socio-economic assumptions have been used for decades to explore possible futures. Emission scenarios for integrated assessment models, have been used as a basis for climate change projections (figure 5 left hand side).

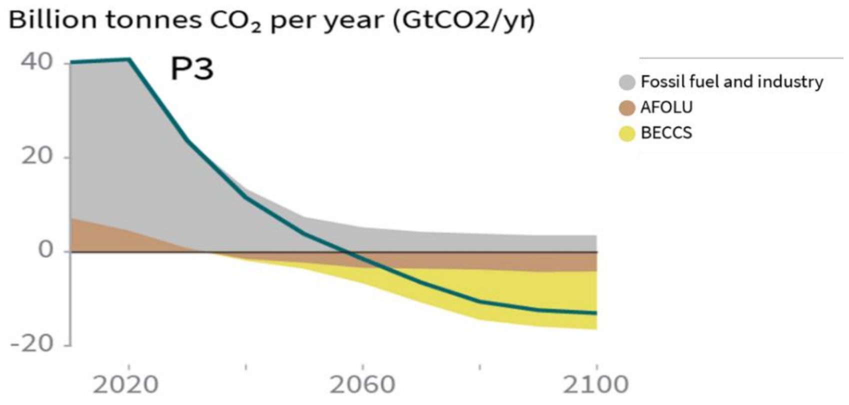
34. The scenario-MIP, part of CMIP 6, has calculated new climate change projections for the 21st century (figure 5 right hand side). Out of a larger set of emission scenarios, there has been a pre-selection of scenarios which have been downscaled and provided to the Earth system models that are now running in the CMIP 6 exercise.

35. The CD-Links[14] and COMMIT[15] project work to connect global modelling teams with national modelling teams and have a range of useful publications.

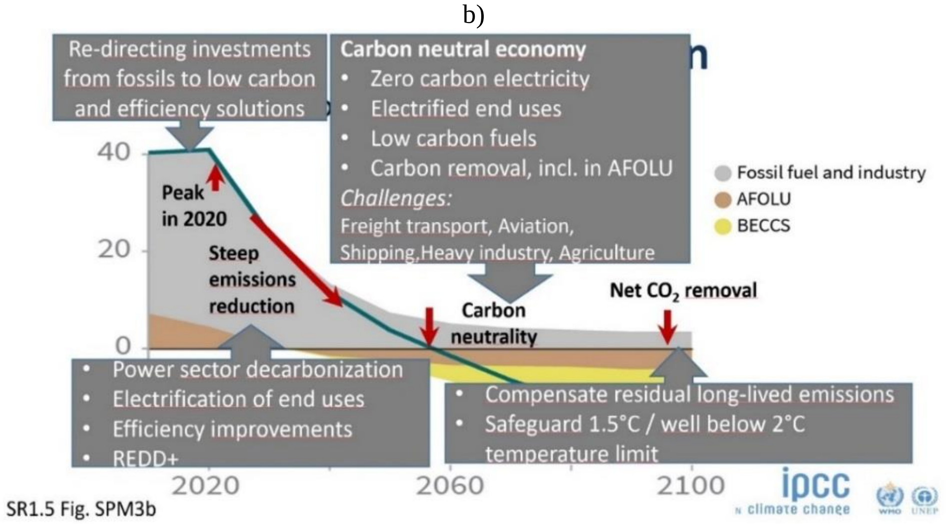
[14] See www.cd-links.org.
[15] See https://themasites.pbl.nl/commit.

Figure 4
The changes in the energy sector required to achieve this P3 scenario, in which average global warming is limited to 1.5 °C above pre-industrial levels

a)

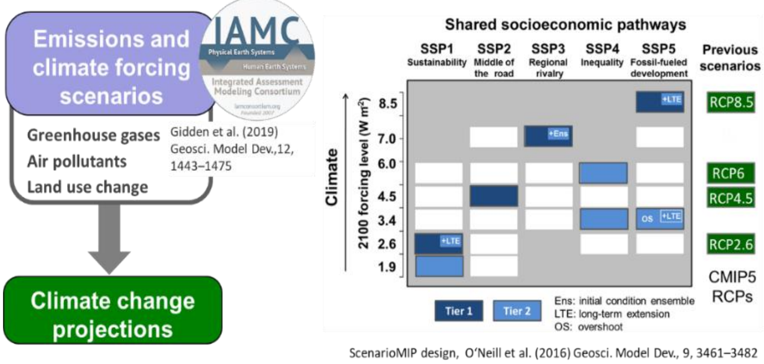


b)



Source: Slide 6 of presentation by Mr Kriegler.
The current generation of socioeconomic scenarios in climate change research is increasingly based on the Shared Socio-Economic Pathways (SSPs). The SSPs offer a systematic exploration of possible socioeconomic futures in terms of widely different predispositions to mitigate and adapt to climate change.[16]

Figure 5
Connecting emission scenarios to CMIP6



Source: Slide 3 of presentation by Mr. Kriegler (from IPCC SR1.5, Figure SPM.3b)
Illustrative model pathways in relation to global warming of 1.5°C. a) Breakdown of contributions to global net CO_2 emissions in illustrative pathway P3 Middle-of-the-road scenario; b) The IAMC 1.5 °C scenario explorer hosted by IIASA contains the 1.5 °C scenarios that underly the 1.5 °C assessments in the 1.5 °C Special Report.

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16 For a more detailed explanation of scenarios see https://www.climatescenarios.org.

36. **Mr. Jim Skea**, IPCC, focused in his presentation[17] on the following guiding questions: What do you consider to be the priority topics or questions on which we need to develop further research to succeed in the transformation of energy and other systems; and how can innovations in social sciences help achieve and manage the necessary social, economic and cultural changes?

Key messages

- IPCC authors in SR1.5 identified the research priorities for each chapter, in a section entitled knowledge gaps.
- A knowledge gap does not imply that nothing is known, but that the challenge lies in enhancing the knowledge to fine tune the responses available.
- Research priorities to address knowledge gaps as identified in SR1.5 include those on:
    - Technological and economic aspects;
    - Behavioural and social sciences.
- There is a need to improve the relevance, assessment and communication of existing social science. Applied social science can help understanding of which policies work and, more controversially, which are less successful. Ex-post evaluation in policy responses is very important to enhance policy learning.
- The IPCC AR6 Working Group III will be piloting systematic review techniques in the AR6 chapter on demand, services and social aspects of mitigation.

37. Mr. Skea reminded colleagues that, in the Special Report on Global Warming of 1.5° C, each chapter had a section entitled knowledge gaps. Mr. Skea provided a summary of the **research priorities** identified by the authors of the SR1.5 report for each chapter.

38. Mr. Skea first presented the **technological and economic aspects**. He identified a need for increased understanding in regards to:

- Ambitious mitigation pathways: understanding economic, dynamic and systemic aspects;
- Representing the role of the financial sector in system models;
- Role of regulatory financial institutions and their capacity to guarantee financial stability for mitigation;
- Interactions between mitigation responses and sustainable development and efforts to eradicate poverty;
- Mitigation potentials in the industry, buildings, and transport sector; strengthening sectoral decarbonisation strategies;
- Integration of variable renewables into energy systems;
- Feasibility of upscaling carbon capture and storage (CCS);
- Carbon dioxide removal (CDR): responses other than BECCS (bioenergy with CCS) and afforestation;[18] the impacts of large-scale deployment on environmental and social aspects of sustainable development;
- Understanding impacts of large-scale deployment of carbon dioxide removal (CDR) in terms of environmental and social aspects of sustainable development, bearing in mind BECCS and afforestation are considered in the SRCCL.

[17] See https://unfccc.int/sites/default/files/resource/1.2%20Skea%20IPCC.pdf and audio broadcast 0:034:45.
[18] Covered in further detail in IPCC SRCCL.

39. Mr. Skea then identified **research priorities in behavioural and social science** for system transformation:

- Emissions reduction potential of behavioural mitigation options;
- Enabling lifestyle change in developed and developing countries;
- Enabling change in organizations and political systems;
- Methods for assessing the contribution and aggregated impact of non-state actors;
- Land-use planning in cities, especially where tenure and land zoning are contested;
- Partnerships within local governance arrangements that may act as mediators and drivers for achieving global ambition and local action;
- Multilevel governance, in particular in developing countries, including participation by civil society, women and minorities.

40. He reflected on the wide range of research opportunities identified and praised the work done by scientists in identifying these knowledge gaps. He emphasized that **a knowledge gap does not imply that nothing is known, but that the challenge lies in enhancing the knowledge to fine tune the responses available**.

41. Mr. Skea continued with personal recommendations and identified the following in regards to **how social science can help achieve and manage system transformations**:

- Innovation in social science matters, but more important is the need to improve the relevance, assessment and communication of existing social science.
- National policymaking is often framed in terms of cost-benefit analysis, prioritises quantitative evidence, and sees system change as the aggregation of individual choices. To enhance the degree to which policy making systems absorb the evidence that social science provides, these systems need to take a wider view (for example, of how accepted social practices develop and their cultural dimensions) and accept qualitative evidence.
- Researchers must develop respect for ways of building and integrating each other's disciplines to give insights into the policy making process. In the natural sciences agreed laws exist. In social sciences, however different branches will make different hypotheses on the way human behaviour develops.
- Applied social science can help us to understand which policies work and, more controversially, which are less successful. Ex-post evaluation in policy responses is very important to enhance policy learning.
- It is important that social scientists communicate in languages that policy makers can understand. Bland, high-level statements that provide little practical guidance should be avoided.

42. He concluded that in the AR6 cycle, systematic review techniques are being developed for identifying literature and screening for relevance and quality to input into the IPCC process. The IPCC AR6 **Working Group III** will be **piloting systematic review techniques** in the chapter on demand, services and social aspects of mitigation.

43. **Ms. Marta Torres-Gunfaus,** Senior Research Fellow, Climate and Energy, IDDRI spoke on what the latest research tells us of the key challenges and approaches to achieve the transformation of energy and other systems to hold global warming to well below 2 °C and pursue efforts to limit it to 1.5 °C?[19]

Key messages

- Countries must plan for a robust transformation at national-level including demand-side actions (efficiency and moderation of demand).
- Early investments to foster learning reduces decarbonization costs in the long term.
- The right policy choices and implementations are crucial to foster learning as well as to the creation of a local industry.
- Long- and short-time horizons are not sufficiently articulated when 2020–2030 rigidities are overestimated or contingent on political stance. Risk of lock-ins and stranded assets becomes higher.
- It is essential for country-level assessments to be embedded in a global context, to help identify cooperation opportunities and ensuring consistency with the global objective.
- International cooperation can make an important difference when it is tailored to the needs of a specific country, taking into account countries' exposure to different forms of risks and emerging economic opportunities and is able to help absorbing the challenges of the short-term transition and anticipate the risks of long-term lock-ins.
- Global storylines as defined at country-level may facilitate the conceptualisation of cooperative approaches towards low-carbon societies with regards to several enabling aspects, including access to capital, development of markets, acceleration of innovation or cooperation strategies.

44. Ms. Torres Gunfaus identified that the reflections shared build on the work and experience of the Deep Decarbonization Pathways Project (DDPP) network and the former Mitigation Action Plans & Scenarios (MAPS) programme network of IDDRI.

45. **IDDRI works on national level assessments and the transformation required to meet the long-term Paris temperature goal**. The network works at the national level with the assumption that, for the Paris goals to be achieved, each country needs to understand its role in the transformation and the related socioeconomic impacts and opportunities.

46. She identified that **how national assessments are conducted matters because it is challenging to understand how each sector and subsector at a national level is adapting to meet the Paris goals**. It is difficult to establish a conversation among the relevant stakeholders on what the Paris Agreement means for each sector or subsector. While much scenario development and target-setting at the emissions level has been carried out, the heterogeneity of countries makes it important to carry out national assessments in a way that allows all actors to find a path to reach those targets, and in the correct order. For example, an existing strong sector can fail to develop new technologies (for example electric vehicles in Italy), but also massive industrial expansions do not automatically yield the latest technology (for example PV in China).

47. She also identified that the method also matters because **basing the process on science is key**, **and science must be relevant for policy-making**. Depending on how this work is conducted, institutional capabilities can be increased to establish a national dialogue that will make knowledge actionable.

48. The approach is also important. IDDRI applies a back-casted normative approach which assumes that the country has signed the Paris Agreement. It then seeks to change the conversation among researchers and stakeholders from how ambition could be heightened to what a country needs to achieve carbon neutrality, either at a domestic level or from outside its jurisdiction. The **emphasis** is not on what is feasible, possible or realistic, but **on what the country needs to do to achieve its goal**.

[19] See https://unfccc.int/sites/default/files/resource/1.3Torres.pdf and audio broadcast 0:45:17.

49. An important challenge is that national assessments could easily become an isolated study separated from the global context. **IDDRI's approach benchmarks activities across all levels and sectors to discover what is Paris compatible at the national level while establishing a conversation on how each country sees this transformation being achieved globally**. It is then possible to discuss: possible changes in trade flows, the demand for different sectors, different behaviours, and other drivers.

50. In order to better understand the needs of international cooperation, **the boundary conditions that can be hidden in models need to be made explicit because the effect that international cooperation or the global context will have on a country is important.** She stated that it is hoped that one of the main outputs from current assessments will be finding a smarter way to create the cooperative approaches that are needed.

51. Ms. Torres Gunfaus identified that **further research to succeed in the transformation of energy and other systems includes** research on:

- Multidisciplinarity;
- Interactions between energy and land use;
- Sector-based roadmaps, in particular for hard to abate sectors;
- National-level economic resilience of alternative global future alternatives;
- Case study analysis to help putting modelling results in a broader perspective;
- Ex-ante and ex-post analysis of policy effectiveness;
- Energy demand (efficiency, modernisation, behaviour changes).

52. **Innovations in social science could help achieve and manage the necessary social, economic and cultural changes** through:

- Co-production and stakeholder engagement on pathway development can play a role in the integration of social sciences which, among others, strengthens the robustness of results and helps identifying hidden opportunities and risks (particularly, regarding behavioural changes);
- Improved understanding of political economy considerations (i.e. discourse and networks analysis);
- Structured analysis of governance functions provides a framework to strengthen the capabilities to transform societies. This is found to be most useful at sector-level given the dispersity of gaps and opportunities across sectors.

53. She concluded by stating that, **while models play an important role**, they are not at the centre of the assessments. Instead, **the core of the assessments is composed of a dashboard of other structures that allow a dialogue inclusive of social sciences and other disciplines**. This allows development to be placed at the centre of the discussion, and therefore accounts for how countries see their economies evolving over time and for transparent cross-country comparison. Using this approach, results can be brought into the international debate in a consistent way.

54. **Ms. Riyong Kim,** Climate-KIC, presented on **investing in our future, disruptive systems change and 1.5°C compatibility in the financial system**.[20]

Key messages

- Adaptation and resilience challenges do not exist at one level or just at one scale.
- Research and evidence suggests that tackling resilience effectively means treating it as a part of complex adaptive systems, often meaning outcomes are unpredictable and consequences of actions can be unintended.
- A new approach to strengthening climate resilience is needed if we are going to radically improve adaptive capacity informed by key ideas from the social sciences that:
    - Embraces research and experience of how to unlock change in complex systems;
    - Treats resilience as a fundamental component of socio-economic progress, interconnected across administrative scales and space;
    - Includes innovation as a key way of acting on levers of societal change – such as behaviours and cultures, finance, technology, policy and regulation.
- EIT Climate-KIC is advancing a new approach to adaptation working with 'challenge-owners'.

55. She noted that EIT Climate-KIC is one of the EU's largest Public-Private-Partnerships with 10 years of experience in supporting climate innovation. It is a knowledge innovation community of over 350 partners.[21]

56. She highlighted that innovation is not just about technology. Meeting the challenges of climate change requires innovation across sectors and disciplines. This innovation must be codesigned, co-created and connected to all of its elements before a systems impact can be realized. Experience over the last ten years has given EIT Climate-KIC a foundation to design the systems interventions that can work towards transformations. Financial sector transformation is a key lever of actioning change.

57. The **first key trigger to financial transformation is working with the current financial system to mainstream climate into current financial processes**.

58. She identified that sustainable finance has gained traction over the past few years and has led to significant policy initiatives such as the G20 Taskforce for Climate Related Financial Disclosures (TCFD)[22] which gave climate risk a central position in the context of business continuity and shareholder responsibility. At the EU level the Technical Expert group on Sustainable Finance just released a far-reaching set of recommendations for a taxonomy of sustainability activities, following on from recommendations of the High-level expert group.

59. Innovators over the Climate KIC community have been supported under the Decision Metrics and Finance theme for the past four years to develop ratings, tools and products that can mainstream climate within financial decision-making processes.

60. A recently supported project, the Climate Value- At-Risk metric developed by Potsdam Institute for Climate and Carbon Delta, monetizes physical and transition risk for companies. Another project - Winners works with farmers in east Africa to provide access to credit and cheaper insurance in return for adoption of climate smart agricultural practices.

61. A key question here is however, how we move beyond these incremental approaches, such monetising the risk we face, disclosing them to our shareholders and divesting from "high risk" assets to a logic that helps us invest into transformative systems change?

62. Fundamental shifts in the paradigms that underlie the economic and financial system need to happen: on notions of value, monetization, "externalities", and underlying human behaviours that drive the financial flows, including short-termism. We need to design multiple, connected interventions that can adjust the way we invest.

[20] See https://unfccc.int/sites/default/files/resource/1.4Investing%20in%20our%20future%20SB50%20presentation_simplified.pdf and audio broadcast 0:55:55.
[21] See https://www.climate-kic.org/.
[22] See https://www.fsb-tcfd.org/.

63. **The second key trigger for financial transformation is the role of time. Investments into sustainability are positively correlated to longer time horizons as the benefits or "returns" are realised after certain time period**.

64. For the first time the IPCC SR1.5 presented the P1 scenario, a Low Energy Demand scenario (that focuses on radically more resource efficient delivery of society's needs and importantly a rapid reduction in fossil fuel emissions post-2020, with a relatively small, future contribution from negative emissions.) It demands that we live smarter (if we are not to depend on negative emissions), that is to move away from current patterns of consumption, production and mobility that are locking us into unsustainable pathways.

65. Such a transformation of economic, social and financial systems, aligned with a low energy demand scenario, will demand a change to investment patterns that can lead to "lock-in" of these behaviours. At the same time, society must rapidly identify smarter "green revenue" business opportunities that will support a low energy demand future – and these solutions will often have nascent or underdeveloped markets, as they serve societal needs that have not yet become mainstream, but investment needs to occur here. She identified that we also need to work with social narratives that can cultivate longer time preferences and help people become "futures literate".

66. Ms. Kim gave the example of mobility and asked whether the answer is more EVs or should we be rethinking how mobility will look like, and why there would be a need for mobility? Particularly if shifts in society may move, for example, towards shorter working weeks, and community-based activities.

67. Decision metrics play an important role in facilitating such investments. Climate KIC currently works with Mission Innovation to develop an Avoided Emissions Framework that can help calculate avoided emissions in society of any particular solution geared to a low energy demand future. And this is coupled to efforts in promoting long-termism using cultural and social interventions.

68. Key questions and areas of work include:

- How can we use the Internet of Things and big data to provide better, real-time monitoring data, that is democratised and accessible to users and then linked to investment? The availability of such data will be key in facilitating the necessary financial flows towards climate.
- Can Artificial intelligence help predict future social trends and guide the development of innovation?
- How do we represent and respond adequately to needs and demands of the future generations?

69. **The third key concept is on notions of value and accounting of "externalities."**

70. Ms. Kim stated that our modern-day economy is built upon a system in which monestised, quantifiable costs can be accounted for, but where climate change and its effects have rarely been costed such that they remain "external" to the current financial system and have no monetary value. This is where the potential of frontier technologies could play a role, coupled with policy and social innovations.

71. She identified one innovation that Climate-KIC are supporting is REDDchain, which uses technology to improve the real-time monitoring of forest conservation under the REDD+ mechanism. Through digital ledger technology (DLT) the team are developing smart contracts that will facilitate investments in return for verified units, for avoided deforestation. Our pilot case is currently running in Chile, with full results of this digital transaction due to be showcased at COP 25.

72. She highlighted that examples like these are important to showcase how blending technology advances with finance, as well as societal goods and services, helps redefine value in terms other than money, and is a key area of work that needs continuous attention.

73. She identified that, like the outcomes of Resilience Frontiers,[23] Climate-KIC seek to understand how we can leapfrog the need for monetized business cases: and how technology can play a role, together with political, social and cultural innovations.

74. She concluded by stating that the systems innovation approach connecting multiple experiments and interventions, is crucial to meet the complex challenges posed by climate change.

[23] See http://www.resiliencefrontiers.org/.

75. **Mr. Carlos Fuller,** Belize provided **perspectives on behalf of Belize and the 14 Parties of the Caribbean Community**.[24]

Key messages

- Increased NDC ambition is possible given the current renewable energy revolution.
- Transitions in the workforce to achieve the 1.5 °C target can occur without the massive disruption envisaged by some predictions.
- Renewable transition brings profound sustainable development and economic benefits for most countries.
- All countries need to transition to net-zero and this transformation needs to be based on science.
- Need to take advantage of the latest science including the special report on 1.5°C to inform new rounds of NDCs by 2020.
- AOSIS countries are leading the way with ambitious NDCs and climate action, but all can profit from more science on 1.5°C transformational pathways on the country level.
- Savings in the cost of importing fossil fuels, once national renewable energy solutions are developed, can be used to finance adaptation.

76. Mr. Fuller identified that SR1.5 describes how to limit global temperatures to 1.5 °C. Action must be taken now, and emissions must be reduced by 45 % by 2030 relative to 2010, and net zero emissions must be achieved by 2050. Failing to do so means missing the 1.5° target.

77. He identified that the good news is that a renewable energy revolution is underway. The **rate of decrease in the cost of renewable energy and storage systems over the last decade has been unforeseen and is projected to continue**. **The NDCs's submitted prior to COP21 or from 2014 were formulated without this knowledge. This new knowledge indicates the potential to increase ambition**.

78. The Alliance of Small Island States are calling for such an increase in ambition. They propose that small island states submit updated NDCs at the UN Secretary General's summit on the 23rd of September to lead the way in heightening ambition and call for similar actions from other Parties.

79. Cost reductions have been observed for wind, solar, and other renewable energy technologies (figure 6). The greatest cost reductions have occurred in solar photovoltaic systems. In some regions, solar energy is now the cheapest source of energy.

80. Mr. Fuller highlighted that **renewable energy can bring about profound sustainable development and economic benefits for most countries**. For example, previously in the Caribbean the cost of importing fossil fuels comprised 60% of the Caribbean foreign exchange. With the switch to renewable energy, the subsequent 60% savings could be used to undertake the change that is required to adapt to the 1.5 °C of warming that is already locked-in.

81. All countries need to transition to net zero by mid-century and that transformation needs to be based on science. The latest science must be taken advantage of, including SR1.5, to inform new rounds of NDCs by 2020.

82. He stated that AOSIS will lead the way with more ambitious NDCs and climate action in order for all to profit and benefit from the science of those transformational pathways.

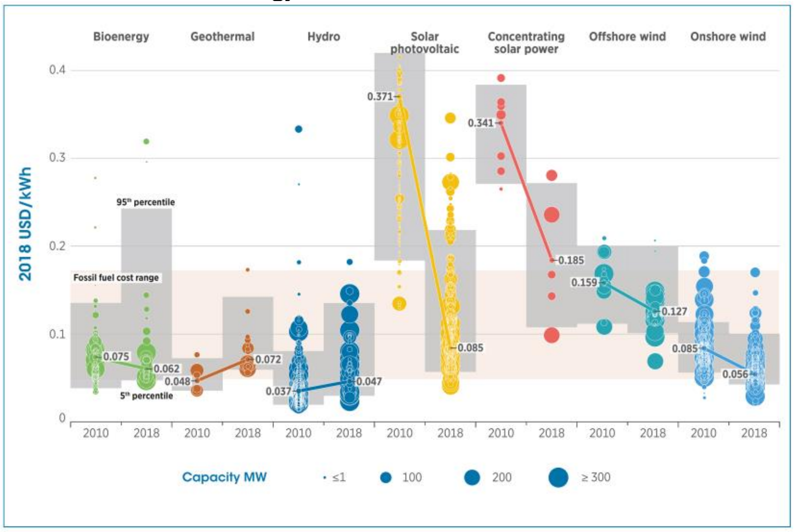
83. Mr. Fuller directed delegates attention to the poster on what sea level rise means for the Caribbean and identified the great number of infrastructure facilities, including airports and ports - the only source of imports into the Caribbean, that will be affected.[25]

84. He identified that Barbados is a principle manufacturer of photovoltaic water heaters in the Caribbean and exports to other Caribbean countries and to Africa. Thus, the transformation of the workforce

[24] See https://unfccc.int/sites/default/files/resource/1.5Energy%20Revolution.pdf and audio broadcast 1:05:07.
[25] See Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of SIDS, UNCTAD, https://unfccc.int/sites/default/files/resource/3.4UNCTAD_Asariotis.pdf.

is already underway and has occurred without the massive disruptions that some had anticipated. This is already an example of the transformation required to achieve the 1.5 °C limit.

Figure 6
The cost reduction of renewable energy over time



Source: Slide 3 of Mr. Fuller's presentation.
Original source: Renewable Power Generation Costs in 2018, IRENA,[26]
from Figure S.1 Global levelised cost of electricity of utility-scale renewable power generation technologies, 2010–2018

85. **Mr. Harald Winkler,** South Africa, **presented on transforming South Africa's energy infrastructure and how climate can finance the accelerated phase out of coal for electricity.**[27]

Key messages

- Renewable energy, wind and solar PV, is now least cost, so coal declines in modelled reference case.
- However, there is a need for climate finance to accelerate phase out of coal.
- An accelerated phase out of coal would: reduce emissions from coal stations; and create space for new renewable energy technologies.
- Just transition is the priority: transitioning from coal to renewable energy and energy efficiency, leaving no-one behind.
- The political economy of phase out must be considered including how to manage change for workers and communities dependent on coal.
- Research is needed on innovative financial and associated mechanisms to facilitate transformation of (energy) infrastructure.

86. Mr. Winkler identified that the **just transition is a priority research gap: transitioning from coal to renewable energy and achieving energy efficiency, while leaving no one behind - so that the transition is just**. **Specifically, how can climate finance help to transform energy infrastructure**?

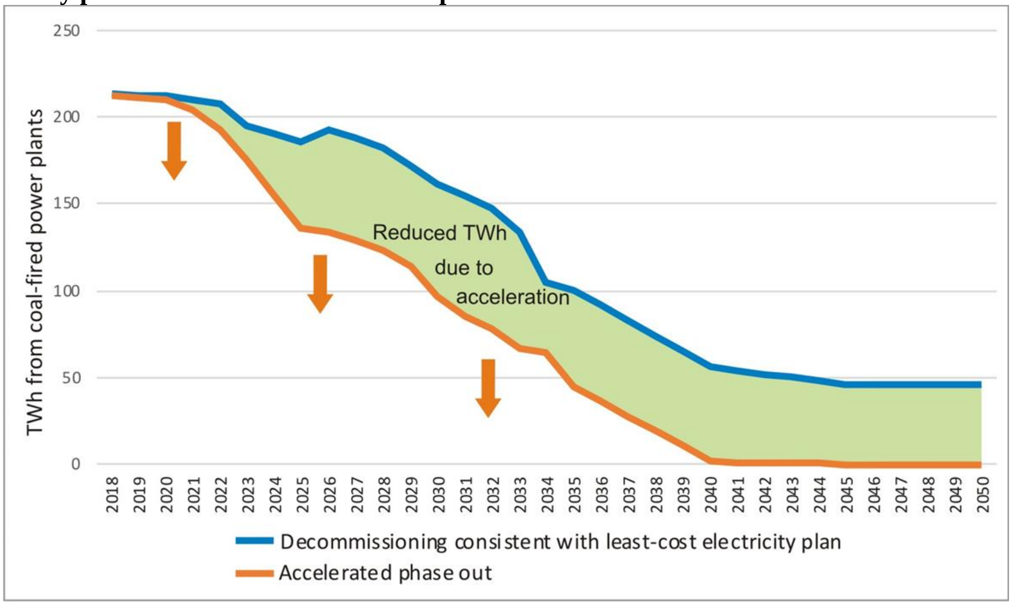
87. He noted that, in South Africa, they are exploring how climate finance can be used to phase out coal while keeping in mind national issues of debt, unbundling and employment creation. South Africa is working on equitable coal transitions together with IDDRI and teams in other countries.

88. He stated that the main issue is that finance of a different kind is needed. This is because finance is not so much needed to enable green technology to fund the incremental costs of renewables for wind and solar photovoltaics as in the past. In South Africa, these technologies are already cheaper than using coal. However, finance is needed to make big changes in emission reductions by funding an accelerated phase out of coal.

[26] See https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf.
[27] See https://unfccc.int/sites/default/files/resource/1.6HWinckler.pdf and audio broadcast 1:10:40.

89. Figure 7 is based on modelling carried out at the University of Cape Town. It identified the least cost electricity plan (blue line) that includes phase out of coal stations, many of which are coming to the end of their lives in the near future and should be replaced by cheaper renewables. It also identified an accelerated phase out pathway (orange line) to directly reduce emissions from coal-fired power stations and, importantly, create space for new renewable energy, with associated socio-economic benefits (employment).

Figure 7
The reduction in Terawatt hours of power from coal-fired power stations under a least cost electricity plan versus an accelerated coal phase-out



Source: Slide 2 of Mr. Winkler's presentation.
The graph shows different financing models, blending across grant, concessional and commercial.
Scale of ZAR 200 bn / EUR 15 bn. Catalytic component is concessional finance, e.g. 6% below commercial rates, with both SA Treasury and Eskom as part of the deal.
Orange arrows show incentives to overperform – additional concessionary rates, or sell ITMOs

90. Mr. Winkler identified that, **to make the energy transformation, firstly it is necessary to unbundle a vertically integrated utility and to protect the system operators, as the current grid system is required to transition to a more decentralized system. Investment used to phase out coal must create socioeconomic benefits, and more research is required on the innovative, financial and associated mechanisms involved**.

91. Financing models that blend transitional and commercial finance indicate that approximately 200 billion South African Rand (15 billion Euro) is required. Concessional finance provided by the national treasury or the national utility at 6% below the commercial rate is considered to be necessary to catalyse the phase out. Incentives to overperform should also be built into the system (go beyond the orange line) through additional concessionary rates or possibly by selling Internationally Transferred Mitigation Outcomes.

92. Experiences with directly financing coal phase-out must be considered as well as learnings from other phase out processes.

93. Mr. Winkler emphasized the importance of processes to achieve just transition and that more research is needed to understand these social processes that seek a new understanding of climate finance and a social compact between different spheres of government, industry, civil society and labour unions.

94. A dialogue has been facilitated by the National Planning Commission through broad consultation as part of Vision 2050,[28] which is to inform a summit, provisionally planned in 2020, to try to reach a new social compact. More information is needed on how to support communities that are currently dependent on coal for example through training and reskilling of workers.

[28] See https://oneworldgroup.co.za/wp-content/uploads/2019/10/NPC-JT-Vision-and-Pathways-draft-2-final.pdf.

Summary of Discussions[29]

95. How helpful are scenarios in overcoming bottlenecks in coordination?

Mr. Kriegler: Scenarios are very helpful for the research community to coordinate themselves. There is also increasing interest in scenarios from, for example, the finance sector, who are interested in assessing the transition risk under a 2 degree climate policy. Researchers work actively with these groups to communicate different types of scenarios. If other societal actors are also looking at scenarios then coordination with and among them also becomes easier. Actors do not need to consider the same or only one scenario, a set of scenarios can be used to frame discussions.

96. Is anything being done to help scientific disciplines understand and value each other?

Mr. Jim Skea: This is a slow and challenging process. People must be brought together to understand the different ways they might use the same language. The three Special Reports are bringing together different disciplines in an unprecedented way. The final chapter on demand, services and social aspects of mitigation represents many people from different disciplines in social science. It is essential to solve this problem in the long term.

97. How do you deal with political bottlenecks? How to deal with being a 'loser' in this scenario, given that an unfair transition will result in the creation of winners and losers?

Ms. Torres-Gunfaus: The point of building pathways is not to follow a particular path but to try and anticipate vulnerabilities. Both anticipated winners and losers are interested in being part of that debate and understanding their way out. In many model scenarios many concerns must be addressed, for example affordability at the domestic level, mobility and distributional issues, the diversity of supply, the competitiveness of industries that may have not been investing as much as others in neighbouring countries. On the political side, one of the things IDDRI does is backcast to include previous NDCs. The rigidities between 2020 and 2030 are probably much larger than just the effect that can be anticipated by considering the policies, packages and commitments that are already in place. Many governments IDDRI works with have scenarios that do not match their 2030 NDCs. To reveal the full range of future options it may be necessary to work in the short term. That is sometimes incompatible with existing commitments.

98. When looking at climate risks, are you able to factor in black swan events such as climate migration, wars, etc? Are you able to financially model for those disruptions?

Ms. Kim: The example I gave on the climate value and risk is the first metric that attempts to monetise such a complex science like climate science. It is very difficult to take all the impacts that we can potentially imagine under different scenarios and put a money figure to that. This particular metric is the first step in exploring that although more research work needs to be done.

99. How do communities see changes intended as a just transition and are they involved in understanding the transition necessary? What does fairness and justness look like?

Mr. Winkler: Within the last two years or so we have had two labour unions, the unions of mine workers and metal workers, take the government to court to stop new renewable energy. Representatives from these unions were present at the concluding conference of the national planning commission on the just transition. The key statement made was that while a debate can be had on net zero carbon the key phrase is 'leave no one behind'. is the unions do not oppose renewable energy, but privatization and faour a 'developmental state'. People who cannot see their own future in the future that is imagined for them will not come along. It is a continuing conversation that will hopefully end in a social compact.

100. Considering the role of aerosols in systematic observation, much focus has been on observing other meteorological aspects such as rainfall and temperature but in the near future there will be increased importance on observing aerosols influencing or changing the rainfall patterns in developing countries. Zimbabwe expects its rainfall patterns to be heavily influenced by changes in aerosols in the future but there is very little observation done in terms of aerosols. Are there attempts being made to increase the observation of aerosols?

Ms. Lee: A continuous effort is being made by the WMO in particular and other partner organisations and the global coordination of observing networks. The most outstanding example discussed under RSO is the Integrated Greenhous Gas Information System which is not only on observations but also on rationalising observation networks, data process applications, and monitoring components. The role of aerosols in the climate system and how the climate system affects atmospheric aerosols is an increasing concern and an emerging issue. The IPCC also deals with the topic of short-lived climate forcers and there

[29] Audio broadcast 1:20:18.

was an expert meeting on this topic in 2018. The research community is working on aerosols and it is one of the emerging issues that needs continuous support from the Parties.

101. Concerning the WCRP's strategy and the temporal and spatial variation resolution mentioned, there appears to be a gap between what you are suggesting and what the space observation community can provide. Can you comment on that?

*Ms. Boram Lee***:** Global scale coordination exists on satellites – the CEOS/CGMS. It is important not only to increase the density of observations but also to operationalise coordination with the institute so that sense can be made out of the collected data and information. It is an ongoing effort.

102. This is a great opportunity for a small island to engage with the experts. We are not at the moment on track to achieve the 1.5 limit of the Paris Agreement, but we are rather heading towards a 3 degree increase in temperature. Could one of the panelists comment on the implications of the current NDCs in terms of the ability to achieve the 1.5 limit?

Mr. Fuller: Consider where the carbon goes - into the oceans, into the Caribbean Sea. The ocean is *acidified* which affects the ability of the coral reefs to grow and crustacean's ability to grow shells. Secondly, 90% of the heat from global warming is absorbed by the oceans and leads to increased severity and frequency of coral bleaching and hurricanes. The current 1.1 °C rise is already causing significant impact across the Caribbean. At 1.5 the Special Report indicates worse effects, but also a 60% chance of mitigating them. At 2 degrees there is only a 10% chance to adapt, and at 3 degrees the effect is catastrophic.

C. Panel discussion 2: Transformative adaptation and climate resilient development

103. **Ms. Debra Roberts,** IPCC, presented on transformational Adaptation and Climate Resilient Development Pathways.[30]

Key messages

- Transformation requires both transformational adaptation and climate resilient development pathways.
- Pathways that limit global warming to 1.5 °C with no or limited overshoot are characterized by changes in four systems: energy, land and ecosystem services, industrial systems, and urban and infrastructure. Cities, as the largest socio-ecological system represent a global opportunity for transformation.
- Opportunities for agency to enable transformation include enhancing multilevel governance, institutional capabilities, lifestyle and behavioural change, technology innovation and transfer, and policy instruments and climate finance.
- Transformation requires the largest social-economic changes society has ever made and should not be underestimated.
- Priority research include: how do equity, justice and rights reduce risks and promote adaptive capacity and resilience; how to best harness the urban opportunity; and how to deal with informality.

104. Ms. Roberts stated that the impacts of climate change are now so pervasive that they affect every aspect of life and every aspect of the natural systems that support life. This is evident in the IPCC SR1.5 which focused on assessing the science to meet the goals of Sustainable Development and factoring in the need for ambitious adaptation and mitigation action while eradicating poverty and achieving social justice.

105. Two important concepts emerged within the SR1.5 in regards to what is needed for transformation:

- **Transformational adaptation** entails changes in the fundamental attributes of socio-ecological systems and how people interact with each other, with the economic system, and with nature in order to increase adaptive capacity to deal with the non-avoidable impacts of climate change.

[30] See https://unfccc.int/sites/default/files/resource/2.1_%20DRoberts.pdf and audio broadcast 1:33:58.

- **Climate resilient development pathways** identify the deep societal transformations required to put in place the ambitious mitigation that does not exacerbate inequity or human rights issues whilst, at the same time, pursuing a sustainable development capacity that magnifies and enhances adaptive capacity. These climate resilient development pathways that can limit global warming to 1.5 °C with no or limited overshoot are all characterized by rapid, far-reaching and unprecedented changes in four systems where the transformation needs to occur: **energy, land and ecosystem services, industrial systems, and urban and infrastructure**.

106. In regards to the urban and infrastructure systems, cities are humanity's largest socio-ecological system. Urbanisation is occurring more rapidly than ever before, and cities therefore represent a top opportunity for transformation action.

107. Facilitating rapid transformational action requires considering opportunities for agency. The SR1.5 assess these opportunities **and identifies five opportunities for agency**:

- Enhancing multilevel governance;
- Enhancing institutional capabilities;
- Enabling lifestyle and behavioural change;
- Enabling technology innovation and transfer;
- Strengthening policy instruments & enabling climate finance.

108. There are a number of key challenges in achieving the transformation vision, which represents the largest societal project that has been undertaken.

- Structural challenges include: accelerated change in multiple global systems simultaneously across many scales; and addressing the uneven distribution of power whilst not exacerbating poverty, vulnerability to climate change, or other injustices.
- Substantive challenges include a number of constraints which continue to hamper progress on adaptation monitoring and evaluation including an absence of comprehensive and systematically collected data on adaptation to support longitudinal assessment and comparison, and a lack of agreement on indicators to inform progress.

109. Ms. Roberts identified a number of priority areas of research are:

- How do equity, justice and rights reduce risks and promote adaptive capacity and resilience?
- How do we **best harness the urban opportunity?** SR1.5 chapter 5 states "It is difficult to imagine how a 1.5°C world would be attained unless the **SDG on cities** and **sustainable urbanization is achieved in developing countries**, or without reforms in the global financial intermediation system."
- What is the **extent and nature of the challenges posed by informality, and the nature of policy interventions on informality that simultaneously respond to climate change and vice versa?**

110. Concerning innovations in social science, Pelling and Garschagen[31] highlight three important aspects:

- Researchers must **stop talking about the most vulnerable and provide room for them to speak** for themselves - researchers and funders should develop formal processes for scientists and locals to co-produce knowledge.
- Researchers need to combine data and methodologies from political, social and Earth-system sciences to **model risk holistically from local to global scales** – integrate inequality into impact modelling.
- Researchers need to identify **adaptation interventions that focus on social vulnerability** to bring disparities to the foreground.

[31] Pelling M and Garschagen M. (2019). Put equity first in climate adaptation. Nature.569(7756): 327–329. doi: 10.1038/d41586-019-01497-9.

111. **Ms. Hindou Oumarou Ibrahim,** IPACC, **presented on transformative adaptation and climate resilient development.**[32]

Key messages

- Transformation must allow people to live in harmony with nature and with the ecosystems from which their life, food, medicine and all else is derived.
- Action must prioritize the survival of people, ecosystems and the planet.
- Scientific and traditional knowledge must be respected equally to enable transformation.
- Indigenous peoples' knowledge has grown over generations and can inform the adaptation initiatives necessary to enhance community's resilience.
- Knowledge must be co-produced by scientists and indigenous peoples to make it actionable.
- Several processes are needed to achieve knowledge sharing and enhance climate adaptation and resilience:
    - Give people far from decision making a voice to allow them to contribute to the process by guiding research and implementing local solutions;
    - Take urgent action to map natural resources and implement sustainable resource management;
    - Establish dialogues to share knowledge, build resilience and provide a long-term vision beyond 2030 and the SDGs.

112. Ms. Ibrahim identified that transformative adaptation for resilience is a **(re-)connection to the global ecosystem, which would drive individuals, communities and societies to assume their responsibility in the stewardship of nature** and is **necessary to ensure the resilience of humanity to the future impacts of climate change**. Ms. Ibrahim emphasized that transformation allows people to live in harmony with nature and with different ecosystems by respecting that these provide life, food, medicine and all else. The priority in terms of resilience and adaptation must be the survival of all people, all ecosystems and the planet.

113. She also identified the importance of technology, which when used justly and equitably, can benefit those people who have been left behind and allow them to continue to live where they are, to live with the ecosystems and to adapt their knowledge so that technology is used to serve the people who use it alongside their own traditional knowledge.

114. She stated that Chad has already experienced a disastrous 1.5 °C increase in temperature between 1901 and the present day, and peoples in the Arctic and on small islands are also dealing with similar local increased temperature rise. Technology alone cannot affect the change needed over the next ten years to limit warming below 1.5 °C.

115. How transformation can be achieved equitably is a challenge, especially considering how science can prioritise one aspect over others despite indigenous peoples requiring simultaneous, comprehensive action. Science and traditional knowledge must be combined and considered equal.

116. **A top priority for building resilient adaptation is indigenous peoples' knowledge.** The knowledge of pastoralists that is transmitted through generations cannot only be recorded in a report or as a priority, it must continue to be transmitted as it has been done traditionally. Pastoralists' observations of nature and the weather imparts knowledge on resilience and adaptation. The challenge is to focus research on this, and other knowledge equally, and so enhance the resilience of the communities by using combined knowledge to help people to adapt and effect transformation in their lives.

117. **A second top priority is that scientific and traditional knowledge can be co-produced and must be recognised officially at the same level**. Science should not have to confirm the traditional knowledge of indigenous peoples. This knowledge is developed over centuries in communities whereas scientists spend only one to five years confirming the same knowledge. For example, meteorological experts on climate

[32] See https://unfccc.int/sites/default/files/resource/2.2%20Hindou%20%20-%20%20Lecture%20seule.pdf and audio broadcast 1:43:54.

adaptation, on weather forecasting and UNESCO are working on combining traditional and scientific knowledge to produce more comprehensive information.

118. The first process needed to achieve knowledge sharing and so enhance climate adaptation and resilience is to give a voice to the people far from decision-making who live with the impacts of climate change and who are building solutions from their interactions with nature. When these people are aware of how they can participate, they can better guide decision-makers and better implement solutions. **A multi-level dialogue between the state, indigenous peoples, the scientific community, and those who are implementing solutions on the ground is needed as the first step toward putting people at the center of decisions and giving voices to communities.**

119. The second process is taking **urgent action on the ground, for example by mapping natural resources**. In the Sahel, communities are fighting amongst themselves just to access natural resources. There is an urgent need to implement monitoring and sustainable natural resource management. 3D participatory mapping can be used to ascertain how both agriculturalists and pastoralists can access water in times of drought and adapt to and share shrinking resources. 3D participatory mapping can also be used in combination with the work of the IPCC and IPBES to craft solutions that can be implemented on the ground to aid communities in restoring ecosystems and the species and resources that are needed for subsistence.

120. Ms. Ibrahim stated that **dialogue must facilitate the establishment of this process to share knowledge, build resilience and establish a long-term vision beyond 2030 and the SDGs**.

121. **Ms. Candice Pedersen,** Ikaarvik, presented on the development of the **SIKU monitoring app.**[33]

Key messages

- To ensure adaptation for resilience, it is important to:
  - Respect intellectual property and self-determination;
  - Bring together IQ (Inuit Qaujimayatuqangit) and science;
  - Give communities control over how to mobilize knowledge for climate change adaptation.
- Frontier technologies like SIKU can help communities adapt to climate change by providing tools for knowledge archival, information sharing and bringing together IQ and science. This platform can also support ongoing initiatives in the communities, like research (Smart Ice and Ikaarvik), and Inuktitut dialect preservation.
- Communities need to be involved in designing the tools for climate change adaptation. That is how SIKU was developed. People must be involved in making tools more suitable for use in their communities.

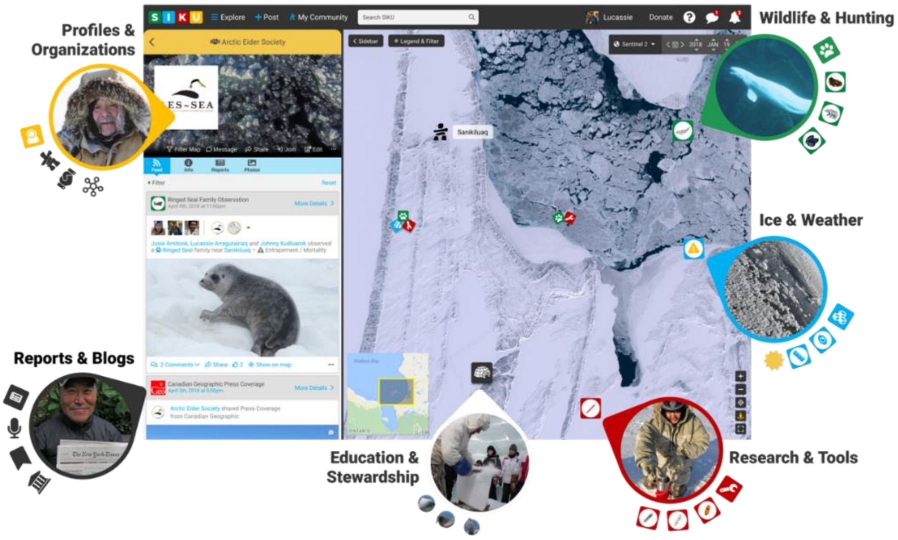
122. **Ms. Pedersen** demonstrated the SIKU app, being beta tested at the time of RD 11, when it reaches its full potential it will be a prime example of **how the Inuit are adapting to a changing world using technology and traditional knowledge to address changes and promote safer hunting and travelling**.

123. She stated that the Inuit have often had to prove their indigenous knowledge, which some scientists view as anecdotal. The app allows a greater level of Inuit self-determination by facilitating the design of their own programs for environmental stewardship and knowledge-sharing with younger generations and the research community.

124. The SIKU app prototype (figure 8), was created by The Arctic Eider Society and the community of Sanikiluaq. It was inspired by Facebook pages such as ‘Hunting Stories of the Day’ which allowed people to share their knowledge and stories with each other. Different communities have helped develop, test and refine the app’s platforms, features and content, including Ms. Pederson’s youth programme Ikaarvik. Users can access, store and share information on ice conditions, weather conditions, wildlife observations and hunting stories.

[33] See https://unfccc.int/sites/default/files/resource/2.3Siku%20presenation%20UNFCCC_Sarah-Candice%20.pdf and audio broadcast 1:58:15.

Figure 8
The features of the SIKU app



Source: Slide 5 of Ms. Pederson's presentation.

125. Each observation can be attributed to a person and project. Specific profiles can be accessed to see each user's involvement. The observations are displayed with an icon on a map which can be overlaid with satellite imagery and topography and users are also able to review imagery from previous dates. Inuit traditional knowledge and science therefore come together in one place where members of the community can access this knowledge and share it with other community members. The app can also be used for education, for example, to teach children about wildlife, dangerous ice conditions and environmental stewardship.

126. New users must agree to the terms of conditions and pledge to comply with the guiding principles of the app:

- To respect indigenous knowledge and rights holders;
- To build capacity for communities to create solutions for environmental stewardship, resource management and climate change adaptation;
- To acknowledge that this information is under the control of the community members who may grant access to it;
- That the information must promote the integrity of traditional knowledge, such as safe ice conditions for travelling and preserving language and culture.

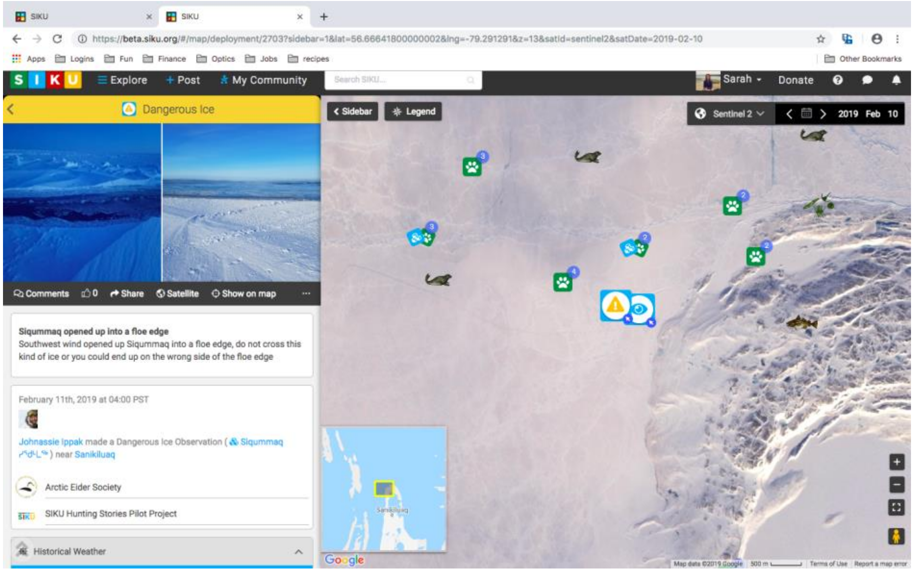
127. The app can track location even out of cell phone range and allows the creation of wildlife observations, hunting posts, sea ice observations and research observations. A large range of wildlife can be observed in the app and recorded in the form of an individual, group, track, family, or den. Observations can also be entered as hunting stories, which requires information on the sex, age, size, and body condition of the animal. For example, a post on the harvest of some geese contains information on their habitat, their coordinates, the method of harvest, their measurements, their stomach contents, and what samples were taken.

128. Another feature of the app is the recording of ice conditions. The app lists different types of ice with a description, a photo and the Inuktitut name of each. This can be used to teach users about the ice and their traditional names. As the app is still in beta testing, posts must be viewed on the website. Tracks and observations observed in the field can be posted from the phone at home and then show up on the website.

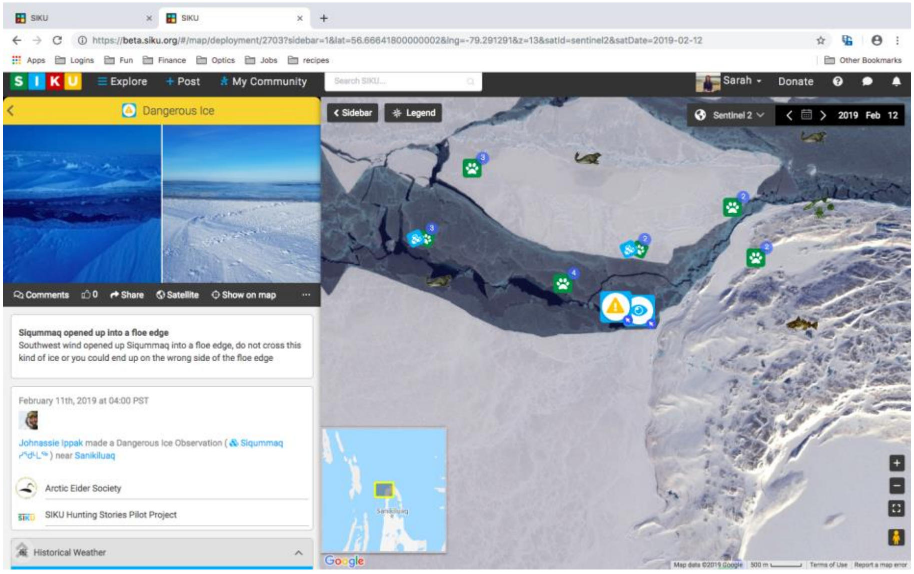
129. In other Communities like Sanikiluaq, sea ice postings are invaluable. For example, dangerous ice can be noticed, photographed and given GPS coordinates even before it shows up on satellite imagery. Ms. Pederson gave an example of dangerous ice that was identified by users of the app that later became a drifting flow edge. A user's traditional knowledge allowed them to identify the ice as dangerous before satellite imagery displayed it and to inform and protect other community members (figure 9).

Figure 9
SIKU – sea ice postings - saving lives

a) A user noted dangerous ice by taking a photo of it and saving its GPS locations (orange symbol)



b) The same location a day later



Source: Slide 16–17 of Ms. Pederson's presentation.

130. This is an example of how traditional knowledge and science can work together to inform SIKU users of dangerous conditions. Climate change has made it harder for the Inuit to predict ice conditions, so this information is especially useful in the spring, to make it safer for families travelling on the ice.

131. Communities have profiles and are actively beta testing the app. It will be fully functional in Autumn 2019 to all regions where Inuit inhabit the land. Inuit are adaptable people and have thrived through many changes in their way of life. This app is one example of adaptation in the era of technology. It will promote environmental stewardship, knowledge transfer and safer travel in a rapidly changing world.

132. **Mr. Tom Mitchell,** Climate-KIC, spoke on the challenges of adaptation and resilience as well as the new innovative approaches that Climate-KIC can offer in addressing these challenges.[34]

Key messages

- Adaptation and resilience challenges do not exist at one level or just at one scale. They are interconnected and systemic. Laws or regulation at national level can influence the range of choices to adapt locally.
- Research and evidence suggest that tackling resilience effectively means treating it as a part of complex adaptive systems, often meaning outcomes are unpredictable and consequences of actions can be unintended.
- We must take a new approach to strengthening climate resilience if we are going to radically improve adaptive capacity informed by key ideas from the social sciences.
- EIT Climate-KIC is advancing a new approach to adaptation looking for and working with 'challenge-owners', who are owners of the problem of lack of resilience to climate impacts. The approach involves:
    - Resilience as a systemic challenge and understanding the major blockages;
    - Involving diverse and unusual innovation actors as co-creators;
    - A portfolio approach using multiple rapid interventions, innovations, in the system simultaneously, directed at different levels of change;
    - Rapid learning about connections and impacts that cull what isn't working and recognizing effects and scaling up what is working;
    - Action informed by social science work on complexity theory, on complex adaptive systems, transition dynamics, social tipping points;
    - Learning from the UNFCCC Resilience Frontiers approach.

133. Mr. Mitchell stated that the **challenges of adaptation and resilience are fundamentally systemic**. They are connected across scales and cannot be considered in isolation. For example, regulation or policy set at a national level can completely determine the range of choices available to people at the local level, or the way in which international trade regimes decide and influence the way local people or investment strategies work.

134. **Working at one particular geographical scale of adaptation or on one particular system does not allow the achievement of the needed transformational effects**. For example, the Common Agricultural Policy of the EU often means that farmers choose to behave in a way that increases flood risk. Considering adaptation of one particular part of a system will not achieve the effects that are needed.

135. **Adaptation and resilience exist in a complex system landscape**. Adaptation projects are often conducted in isolation with a set start and end date. They are often mandated to achieve a set of outcomes and key performance indicators, and to produce a report for a funding body or organisation. Time is rarely taken to learn from the findings of the project, and innovation is sidelined in favour of creating the latest report or set of KPIs. Deviation from that core path is challenging.

136. This **mode of adaptation in the last 10 to 15 years has not yielded the required results or transformations**. Practitioners are programming and working in ways that do not align with how social sciences and the IPCC have described the adaptation needed in terms of complex adaptive systems.

137. Mr. Mitchell highlighted that **it must be accepted that the outcomes of work done within the complex adaptive systems approach will be initially unknown**. How systems will react to change is unpredictable, and there can be unintended consequences. However, **social sciences also provide guidance on how to act in those circumstances and can therefore indicate a programming direction**.

[34] See https://unfccc.int/sites/default/files/resource/2.4Mitchell.pdf 2:07:23.

138. **Climate-KIC has started to work on and practice a new way of thinking about working on resilience**. This process is **referred to as deep demonstration**. The method is transferable to many different locations.

139. Mr. Mitchell highlighted how EIT Climate-KIC is already **advancing this new approach on the ground, working at regional level in Europe** – with some of Europe's most climate exposed regions. It provides a recipe for transformation for resilience and involves working with 'challenge-owners', who are effectively owners of the problem of lack of resilience to climate impacts. In the case presented, he stated that they are starting with four regions and four regional governments – Andalusia (Spain), Dolomites (Italy), Nouvelle Aquitaine (France) and Clyde (Scotland). The approach involves:

- Resilience as a systemic challenge and understanding the major blockages and developing an active, sense-making process, not focusing on producing a scientific report;
- Involving diverse and unusual innovation actors as co-creators;
- A portfolio approach using multiple rapid interventions – innovations – in the system simultaneously – as a portfolio of effects directed at different levers of change (skills, finance, technology, policy, behaviours);
- Rapid learning about connections and impacts – culling what isn't working, seeing effects and scaling up what is working;
- All the above is informed by social science work on complexity theory, on complex adaptive systems, transition dynamics, social tipping points;
- Learning from the UNFCCC Resilience Frontiers approach.

140. Mr. Mitchell identified that EIT Climate-KIC has a 10-year back catalogue of working on climate resilience innovation across Europe and can mobilise both that learning and capability to crowd in innovation around single regions, working through start-ups, innovation projects, and practical experience. A portfolio of interventions may include, for example:

- On technology - trial new building materials that self-strengthen under higher wind speed;
- On finance – offer insurance of credit guarantee mechanisms, to offer resilience investment loans to poor people;
- On behaviour shifts – harness the capabilities of marginal people in society to act as resilience ambassadors in communities;
- On policy and regulation – resilience labelling, only allow landlords to rent out buildings if they meet a minimum resilience standard;
- On information – open data on resilience for all, available in accessible formats, forward looking, and linked to action options.

141. Mr. Mitchell emphasised that, **as tipping points are reached, a new mode of operation is needed**. Climate-KIC is treating climate change as a state of emergency, requiring a different approach to transforming our systems and a very different approach to programming.

142. **Mr. Tomohito Yamada,** Japan, presented research work on a**daptation measures for extreme floods using huge ensemble of high-resolution climate model simulation in Japan**.[35]

Key messages

- Dynamical downscaling of both past and future climate conditions has provided estimations of extreme conditions for precipitation.
    - Extreme heavy precipitation in future climate could occur even in the past climate but with lower probability;
    - Extreme precipitation will be stronger in the future and more intense both in temporal and spatial scales;
    - Risks of disasters by heavy precipitation will be higher in the future.
- Based on the calculated probabilities, the research advised future flood control policy at national and sub-national level.
- Research priorities include:
    - Further quantifying certainty and uncertainty concerning the limits of the climate system to improve decision-making;
    - Anticipating the effects of a combination of risks, such as earthquakes and typhoons;
    - Social science must be used to contextualise research on the physical nature of climate change within the broader context of climate action.

143. Mr. Yamada explained that the study focuses on floods and heavy rainfall occurring in both the past and future climate of Japan, using thousands of ensemble simulations applied both for the past and the future to quantify the limits of the climate system. He stated that one of the important messages from the study is that history represents only one outcome of a range of modelling possibilities but, of course, is an important sample.

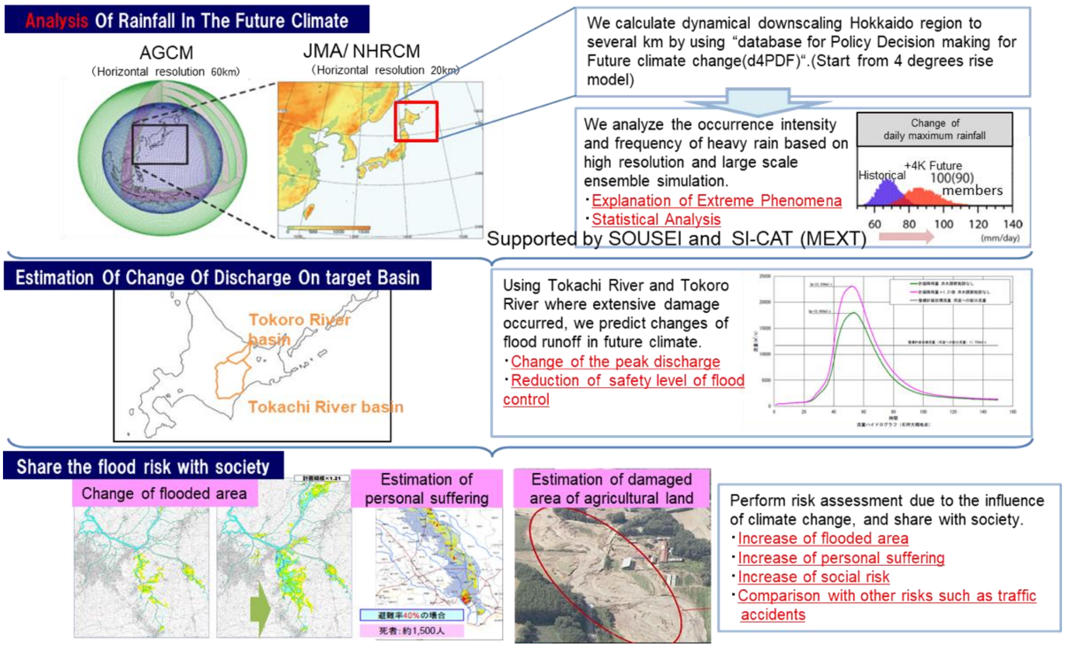
144. As background to the research, Mr. Yamada identified that in 2016 the Hokkaido region in Japan experienced four sequential typhoons and the equivalent of a year’s worth of rainfall within two weeks. This situation was reflected across Japan during this year in many areas. Traditionally in Japan, flood control policy was based on historical information but, as Japan now experiences new records of temperature and precipitation almost every year, the local and central governments in Japan launched a committee to discuss future flood control policies.

145. The mission of the research was to scientifically predict the influence of climate change (rainfall and discharge change) in Hokkaido based on the latest knowledge and calculate the change of risks (including scale, form and frequency) due to the influence of climate change and share the outcomes with society.

146. Mr. Yamada explained that limited historical observations are available even in developed countries, with only sixty to seventy years of rainfall data having been recorded and widely used for decision-making. To supplement this recorded information, the study, funded by the Japanese government, produced thousands of climate simulations both globally and regionally on a 20km grid. However, 20km grid scale is not precise enough to discuss the local effects of rainfall, so this information was then downscaled in order to estimate the flood risks of past and future climate disasters across many river basins. **This information is now used to discuss future flood control policy on a national level** (figure 10).

[35] See https://unfccc.int/sites/default/files/resource/2.5Tomohito_Yamada_presentation_ver1.5plus.pdf and audio broadcast 2:24:08.

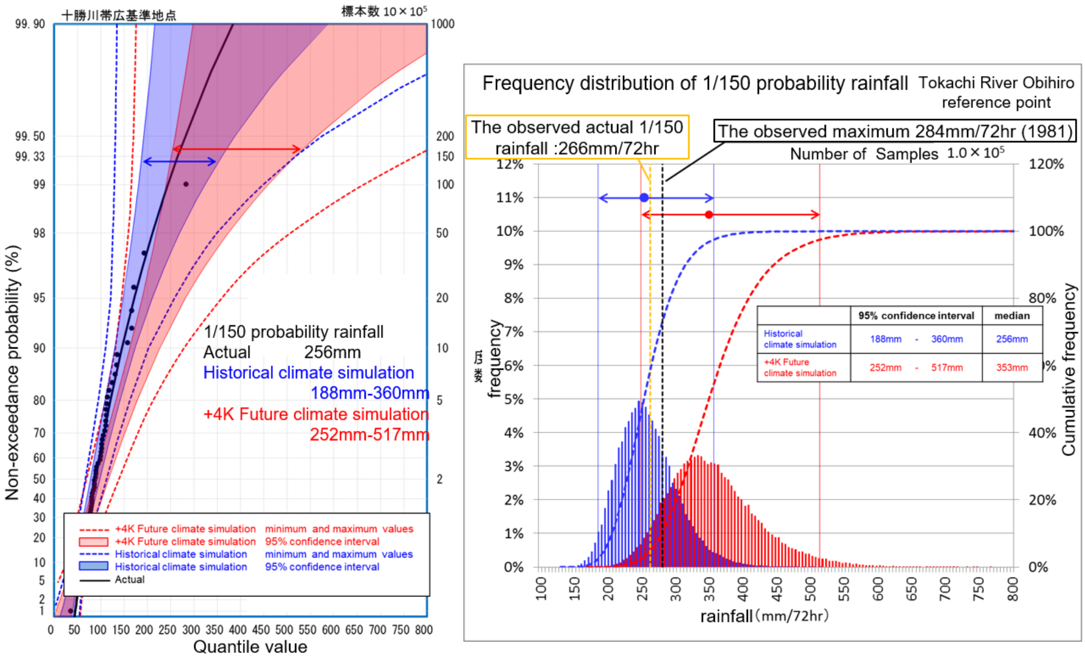
Figure 10
Research process to support the discussion of adaptation policy for future flood control in nationwide committees



Source: Slide 2 of Mr. Yamada's presentation.

147. Mr. Yamada provided further detail of how the team evaluated the probability of historical and future climate rainfall, including under different future temperature changes (increase of 2 and 4 °C compared to pre-industrial) (figure 11). The results of the modelling reveal that the heavy rainfall predicted to occur frequently in the future could have occurred in the past, but with lower probability. These results underline the importance of discussing risk and uncertainty for future flood control policies. The model is supported by both mathematical and physical theory, which enhances its legitimacy in the eyes of government.

Figure 11
Probability evaluation of heavy rainfall occurrence

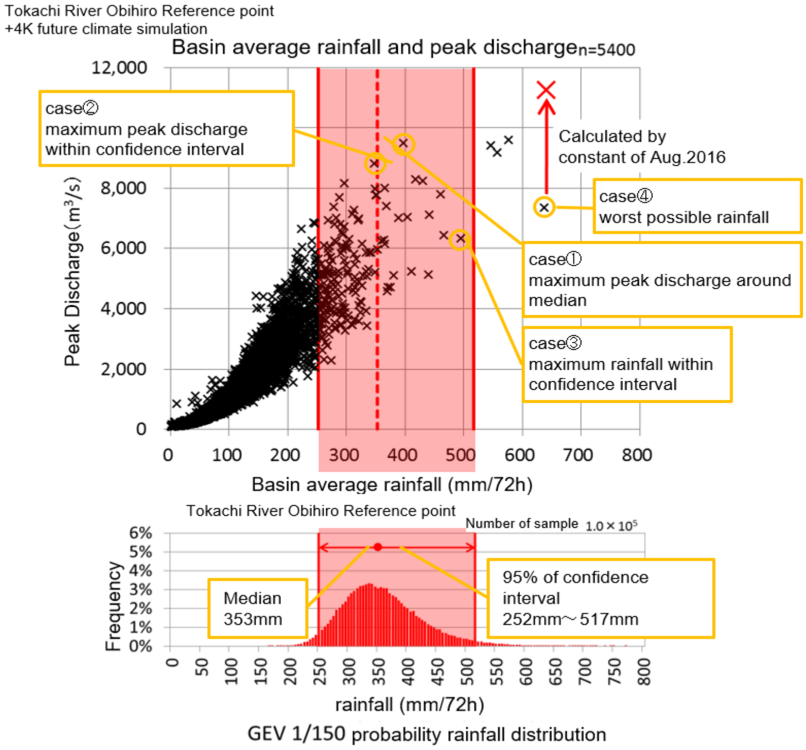


Source: Slide 3 of Mr. Yamada's presentation.
The future climate is represented by the pink area. The past climate is represented by the blue area. The purple section represents the overlap between the past and the future climate.

148. Based on the simulations, peak rainfall and river discharge were plotted on a scatter diagram (figure 12). The results reveal that even if the same amount of rainfall occurs, the peak discharge may double, and that heavy rainfall in the future will be intensified both on temporal and spatial scales. This means that rainfall patterns will differ significantly in the future from patterns today.

149. Mr. Yamada explained that although the central government is responsible for the large river basins, local governments are responsible for smaller river basins and thus the change in risk must be considered at all levels and discussed holistically.

Figure 12
Simulated average rainfall and peak discharge in future climate change scenarios for the Tokachi river



Source: Slide 4 of Mr. Yamada's presentation.
The figure shows the variation of peak discharge in relation to rainfall (top) and the frequency of rainfall amounts over a 72 hour period (bottom).

150. Mr. Yamada concluded by stating that the modelling has provided important input into future flood control policy based on the probability of heavy rainfall. The study showed that extreme precipitation will be stronger in future climate conditions in addition to more intense both in temporal and spatial scales. This means that damage due to heavy precipitation will be more severe. Flood control in future needs to be discussed not only in each river basin scale but also in regional scale (community scale). In addition, studies are needed for risk/benefit assessment by incorporating various types of topics/targets to revitalize the community.

151. There are important research questions in regards to quantifying certainty and uncertainty concerning the limits of the climate system to improve decision-making; anticipating the effects of a combination of risks, such as earthquakes and typhoons; and socio-economic research questions in regards to how to contextualise the physical nature of climate change within the broader context of climate action and human well-being.

152. **Ms. Paulina Aldunce Ide,** Chile, presented on **science and transformative adaptation in the context of Chile.**[36]

Key messages

Social innovation and projects for transformational change need:

- Focus on "how to" practical knowledge;
- Approach research as occurring from within the system being intervened;
- Include ethics aspects;
- Seek to transcend current thinking;
- Acknowledge the value of alternative roles of researchers;
- Focus on transformations.

Research priorities include:

- How can learning and actions be accelerated to lead to transformation?
- Upscaling transdisciplinary approaches to achieve the appropriation of transformative adaptation by different actors;
- Establishing enabling conditions for profound changes at all levels (research communities, institutional and political systems, societal structures): greater integration of research and practice; new forms of training; reconfiguration of institutions; and legitimization of diverse forms of knowledge and knowing.

153. Ms. Aldunce Ide emphasised that actioning social innovation and social projects is difficult. She stated that the key challenges and approaches needed to achieve transformative adaptation must first be identified. Considerations include:

- Focusing on "how to" practical knowledge. Some advances have been made but knowledge gaps remain. To address these gaps, science's role in the co-production of knowledge must be assessed in terms of how it can inform the implementation of change in practice and how it engages with different types of knowledge, such as local and traditional knowledge;
- Approaching research as something happening internally in the system on which the intervention focuses. Researchers must view themselves as inside of the system, implying that when researchers act, they are changing themselves and the world around them;
- Including ethics aspects in the research. Values and norms always shape what is to be researched and how. However, scientists rarely acknowledge the values and ethics that shape their own research, but these should be placed at the core of our research;
- Transcending current thinking and enabling the creation of previously unimagined possibilities. This creates the space to create and innovate. This requires bravery, and may be painful, but it is possible and represents an opportunity to create;
- Acknowledging the value of alternative roles of researchers. Fostering change requires flexibility and the willingness to go beyond the acknowledgement of different roles to actually play them. Researchers must participate in facilitating interactions, mediating between frames and assisting action for the transformation that they are studying;
- Focusing explicitly on transformational change. While some researchers include transformational science in their work, they are unaware of the power of their research. When framing research under transformation, it can provide the opportunity to search for new options for adaptation to climate change, examine different transformational pathways, and investigate the role of types of disruptive change.

[36] See https://unfccc.int/sites/default/files/resource/2.6Paulina%20Aldunce%20Research%20Dialogue%20PAldunce.pdf and audio broadcast 2:16:54.

154. Ms. Aldunce Ide then presented priority topics or questions which should be considered concerning transformative adaptation and climate resilient development:

- How can learning and actions be accelerated to lead to transformation? Transformative adaptation must be accelerated as climate change dynamics move rapidly. Learning must therefore be accelerated to implement transformative adaptation;

- Transdisciplinary approaches must be upscaled to achieve the appropriation of transformative adaptation by different actors. Transformative adaptation is impossible without this;

- Enabling conditions must be established to produce profound changes. These conditions include greater integration of research and practice, new forms of training, reconfiguration of institutions, and the legitimization of diverse forms of knowledge and knowing. This needs to occur at all levels, throughout research communities, institutional and political systems, and societal structures.

155. Ms. Aldunce Ide concluded by highlighting the Transformation Conference 2019 which explores some of the issues highlighted in her presentation.[37]

Summary of Discussions[38]

156. **While acknowledging the need for transformative action, did your assessments address losses and damages such as those of livelihoods, coral reefs, and other things of that nature?**

Ms. Debra Roberts: The SR1.5 has a direct bearing on how loss and damage is considered in terms of transformative or transformational adaptation and refers to a fundamental change in the socio-ecological attributes of systems. How the inevitable impacts of climate change might be responded to must be factored so that loss and damage can be considered within particular systems and be responded to as part of an adaptation package.

There are therefore very strong links drawn to sustainable development if the broad spectrum of change is considered - from being able to adapt in situ through to potential loss and damage which may require a more dramatic response from society and ecosystems. When taking a sustainable development approach to balance these responses, no person, place or system must be left behind.

These complexities were accounted for when considering transformational adaptation and inform the thinking around the climate resilient development pathways, which themselves are ‘all-in’ solution bases. You cannot action adaptation without mitigation, sustainable development or poverty eradication. This is very complex decision-making.

Climate-KIC’s experiments with many projects to tackle various elements of that spectrum simultaneously is interesting. Complex decision trees have replaced more linear solutions in terms of dealing with complexities surrounding things like loss and damage.

Working Group II works closely with issues of indigenous loss and damage, particularly in the main assessment report. The regional chapters of the report provide the key bridge between sectoral understanding and reflection on risk, decision making and climate resilient development pathways.

157. **How will IPCC WG II like to integrate the indigenous knowledge into AR6?**

Ms. Debra Roberts: Within the regions, as we have heard from two of our speakers, a rich basis of knowledge exists. We consider the regional chapters of AR6 an opportunity to make that material known. To do this, we will draw upon experience from the ocean and cryosphere report in which chapter authors have interacted directly with holders of indigenous and local knowledge to find ways of recording that knowledge. Meetings were held with these knowledge holders that can then be referred back to later. In this way, the proceedings of the IPCC were used to access grey literature.

Working with such knowledge remains challenging for the IPCC as it was not designed to access local indigenous knowledge at an equivalent level to scientific knowledge, as clearly highlighted by speakers from local indigenous communities. The people who hold that knowledge consider it equivalent, and the regional chapters of the SROCC acknowledge and draw on that. Authors of chapters of the SROCC met with indigenous knowledge holders in order to find ways of accessing that knowledge. There has been a strong commentary on the SROCC from indigenous communities concerning the way their knowledge was reflected and so that experience exists to be drawn upon.

37 See https://transformations2019.org.
38 Audio broadcast 2:34:50.

Ms. Hindou Oumarou Ibrahim: IPBES has incorporated indigenous knowledge in its reports and can serve as an example to the IPCC. Indigenous peoples can have a meeting to discuss knowledge and this can be used to discuss and produce knowledge and to create chapters. Those indigenous people who have been to school can both author chapters and understand the knowledge. All of our knowledge can thus be handled and be accepted. There must be close collaboration between the facilitative working group under the SBSTA and the IPCC to create these linkages and then come together.

158. **How has technology helped distant communities to share knowledge and learn from each other?**

Ms. Hindou Oumarou Ibrahim: As an indigenous person from cattle-herder pastoralist communities of the Sahel, I see a direct link with my brothers and sisters from the Arctic and Inuit. The same techniques are used to follow the behaviour of the animals and understand how they use natural resources and how indigenous knowledge enables us to find those resources. This knowledge can be shared, for example through the indigenous people's knowledge platform.

One of the pillars of local communities is knowledge sharing and exchange, both between distant communities and those in the same region. For example, the Indigenous People of Africa Coordinating Committee, develops different kinds of knowledge among communities from Burkina Faso, Chad, Niger and Mali to learn what kind of knowledge we have as cattle herders living in different ecosystems.

The nomadic people living on Lake Chad have, for example, six seasons. People who are close to the tropical forest in the Congo basin have seven seasons. On discussing this knowledge, we learn that the six different seasons are identified by living in an ecosystem created by the interaction of the Sahara, the Sahel, and the savanna. The seventh season arises from having the savanna and the forest interact. The sharing of this knowledge helps each community to better adapt when the seasons change. Using the indigenous people's knowledge platform can connect countries and communities across continents.

One method of learning is through Google Earth. We can post knowledge here and give access to it to other communities. This allows them to observe events from a distance and make their own predictions and preparations to adapt. There are language barriers that complicate this but that can be overcome through discussion and through eye contact.

Ms. Candice Pederson: Each community has a hunter's and trapper's organisation that regulates their hunting. This organisation comes together for meetings. We also have many Inuit organisations and regional Inuit associations. These groups come together for these meetings and usually go to the regional communities. The SIKU app also enables sharing of stories which are not shared in person but are still shared in the community. A lot of community knowledge is also shared through Facebook.

IV. Summary of the outcomes of the breakout groups convened at RD 11: prepared by the moderators and rapporteurs of the breakout groups, with the support of the secretariat

Theme 1. Transformation of energy and other sectoral systems to achieve the purpose and long-term goals of the Paris Agreement	
1. What does the latest research tell us of the key challenges and approaches to achieve the transformation of energy and other systems to hold global warming to well below 2 °C and pursue efforts to limit it to 1.5 °C?	The key challenge is managing the trade-offs and exploiting the synergies that the transformation entails, which can be addressed by integrated approaches and policy packages that combine effective action with considerations of fairness and sustainable development goals. Other points or questions: • Important to identifying trade-offs and synergies between long- and short-term actions and priorities, e.g., within different sectors • How do long term strategies help inform short term strategies and vice-versa? How do long term goals constrain short term actions and how does this inform science? What are the feedbacks between long- and short-term strategies?

	• Small carbon budgets leave limited time to act, i.e., there is urgency and every year counts with the speed of actions being quite important • Assumptions about future actions – What if they are wrong? Strategies are needed to make sure alternative assumptions are considered • How do we best do research on this topic? • Prioritize research on timelines that reach goals while minimizing impacts (e.g., allowing time for ecosystem adaptation), i.e., how to reach an end goal while remaining within a safe operating space? • Mitigation pathways could be improved by better accounting for impacts • Just transitions are important; don't leave anyone behind • Improved knowledge of technology potential can change mitigation pathways for better or worse • Implications of the timing of negative emissions – related to challenges • Information on how quickly and efficiently negative emissions technologies can act may not be properly accounted for. What does this mean for mitigation pathways?
2. What do you consider to be the priority topics or questions on which we need to develop further research to succeed in the transformation of energy and other systems?	• Energy-related CO_2 emissions can be reduced by 90% by 2050 through a combination of increased renewables, electrification and energy efficiency. • To achieve this, we need: 1) flexible power systems that can use low cost renewables; and 2) deep electrification of end-use sectors. • Many innovations (across enabling technologies, business models, system operation, and market design) are emerging that can help achieve this added flexibility. • But these innovations must be combined to create real-world solutions that address societal needs in ways that will be accepted, and which are just and fair. • Decision makers need a toolbox of innovations from which they can select those that fit their specific needs while encouraging societal changes tailored for their localities; there is no one-size-fits-all solution. • How are land-use issues linked to decarbonisation pathways? There exists a substantial gap in knowledge in the land use energy nexus, solutions not just technically plausible but also societally acceptable. • Within digitalisation are potential synergies between energy efficiency and grid operation. New technologies could be more efficient in the way they use energy. • We need to learn from what's happening in SIDS with their power systems and help them to apply latest knowledge, particularly related to digitalisation. • More research needed on Africa's biomass reliance. • Are technologies using CCS the best option for negative emissions? Will it actually have a substantial impact?

3. How can innovations in social sciences help achieve and manage the necessary social, economic and cultural changes?	• Learning to work between science, arts, etc.
	• Understanding/Putting to use role of cognitive bias/ social norms in managing change
	• Educational and institutional learning
	• Balancing:
	  o homogeneity with diversity
	  o deductive versus inductive
	• Need to use <u>whole</u> of social sciences – including economics, anthropology, political sciences
	• Innovations don't have to be new, just have to be connected #wellestablished not cutting edge

<table>
<tr><th colspan="2">Theme 2. Transformative adaptation and climate resilient development</th></tr>
<tr><td>1. What does the latest research tell us of the key challenges and approaches to achieve transformative adaptation and climate resilient development?</td><td>Requirement for a change in perception that the consequences of climate change are not direct
Time scales are difficult to handle – action too slow or events are overtaken by climate change
Inertia in policy-making; risks of legal liability; risks of investment– identify a need to understand different perceptions of risk
Political courage to act required
Too many silos in governments
Early action needs political willingness and vision
Think “doable”
Societal dimensions, equity questions, inclusiveness “leave no-one behind”
Co-benefits
Cooperation issues (sectoral and across different interest groups)
Communication issues: How to bring major challenges and needs for actions to public attention
Inter-generational gap in interests</td></tr>
<tr><td>2. What do you consider to be the priority topics or questions on which we need to develop further research to succeed in transformative adaptation and climate resilient development</td><td>Create an integrated research agenda for linked resilience and adaptation solutions, considering a range of issues:
Barriers to transformative adaptation (e.g., complexity, uncertainty)
Understanding the role of local solutions and incentivizing bottom up approaches
Avoiding subsidizing maladaptations
Redefining “value” from purely economic to more inclusive categories
Out of sync time scales for adaptation versus climate change impacts
Science to assess different adaptation strategies and scenarios, including developing indicators -tipping points, both positive and negative, and understanding extremes
Addressing collapse, including of institutions</td></tr>
<tr><td>3. How can innovations in social sciences help achieve and manage the necessary social, economic and cultural changes?</td><td>Leveraging social media and other technology for communications
Circular economy
Common property and the commons
Engaging with the full extent of social sciences (i.e. not just making social science like natural sciences)
Politics and political economy – we need more explicit value judgements among social scientists
Co-production and co-creation of science and indigenous knowledge systems to inform policy
How to extract knowledge from big data and then use it to change behaviour at a broad scale, i.e., can we create online ‘echo chambers’ to spark transformative change?
Need to foster equity, rights, and climate justice</td></tr>
</table>

V. Summary of the posters

159. This section provides an overview of the posters presented and key messages for each poster.

A. Posters with overarching / cross-theme focus[39]

160. Nine posters were presented with an overarching / cross-theme focus and are hyperlinked and summarized below.

Global Climate Observing System: Supporting observations in Africa
Simon Eggleston, Global Climate Observing System (GCOS)

- **Observations underpin understanding and planning to adapt to climate change**.
- The accuracy of all models, forecasts, projections and plans depends on accurate, **high-quality, long term observations**, noting that, in the chain from observations to national forecasts and projections, additional uncertainties are added.
- Even local downscaled models and weather forecasts depend on global observations submitted to global modelling centres.
- **Over Africa observations are not adequate enough** to produce the reliable forecasts and projections needed. Many areas do not report and where data is reported it usually does not meet the requirements.
- **GCOS and the WMO Integrated Global Observing System (WIGOS) are holding regional workshops to address the inadequacy of observations**. A recent workshop for the Lake Victoria region identified a lack of planning and funding to ensure sustainable operation of the existing stations. Planning and funding for consumables, maintenance, equipment replacement, staff retention, staff development, calibration, communication and data retention and archiving is needed. Until these are addressed it is unlikely that additional stations will provide long-term benefits.
- The **GCOS Cooperation Mechanism** assists countries improve their climate observing systems: to collect, exchange and utilise data on a continuing basis. Recent projects in Africa include new surface instruments (Chad 2017), data rescue (Botswana 2017) radiosonde equipment repair and training (Zimbabwe 20166), radiosonde consumable (Kenya 2018).
- WMO has just approved the development of the **Global Basic Observing Network (GBON)** that establishes minimum reporting requirements and resolution for the basic meteorological parameters and should address some of the observational issues.

The GEO Knowledge Hub for Transformative Solutions through Open Science
Douglas Cripe, Group on Earth Observations (GEO**)**

- The Group on Earth Observations (**GEO**) **Knowledge Hub** is a digital repository providing access to knowledge required to build applications of Earth observations. The purpose of the Knowledge Hub is to reveal all components of the application in an open science context, including: (a) research papers and reports describing methods and results; (b) software algorithms and cloud computing resources used for processing; (c) in situ and satellite imagery data used; and (d) results for verification.
- The Knowledge Hub will be useful to a **wide range of stakeholders**, from national experts needing to report on policy commitments, to individual end users and Small- and Medium-sized Enterprises (SMEs) seeking practical solutions to local environmental challenges. With the Knowledge Hub, users will have a single entskeary point to discover and access resources that have been developed by domain experts. Such resources will be of different types to reflect the entire information flow of the research and knowledge pertaining to a domain.
- Activities of the GEO Work Programme will be fundamental in both **providing methodologies for solving problems and identifying potential end users**. Technical experts from research institutions may serve as intermediaries in assisting local end users to benefit from the resources

[39] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-6.

of the Knowledge Hub. GEO intends to leverage the **capacity development** networks of its partners in a “training the trainers” approach.

Special Report on Ocean and Cryosphere in a Changing Climate
Hans Otto Pörtner, IPCC Working Group II

- The Special Report on Ocean and Cryosphere in a Changing Climate (SROCC) builds on scientific questions that emerged from invited government proposals for special reports to be prepared during the IPCC Sixth Assessment Cycle.
- SROCC is developed under **joint scientific leadership of IPCC Working Group I** (Physical Science Basis) **and Working Group II** (Impacts, Adaptation, and Vulnerability).
- SROCC includes six chapters and is developed by 106 selected experts with different expertise from all over the world.
- SROCC will **provide a cross-cutting assessment** including
  i. Role of the oceans and cryosphere in the climate system;
  ii. Risks, vulnerability, and impacts in natural and human systems;
  iii. Responses to enhance resilience, adaptation options, their limits and trade-offs.
- The new and updated information presented to decision makers in this Special Report will **inform the design and implementation of appropriate policies and actions**.
- SROCC will be considered for approval and published in September 2019

AR6 Climate Change 2021: Impacts, Adaptation and Vulnerability
Hans Otto Pörtner, IPCC Working Group II

- The **IPCC Working Group II** contribution to the Sixth Assessment Report (WGII AR6) focuses on the impacts of climate change on natural and human systems, their vulnerabilities, as well as capacities and limits of these systems to adapt to climate change and thereby reduce climate-associated risks together with options for creating a sustainable future.
- The report will build on IPCC reports from previous cycles and also on the three Special Reports that are developed during the Sixth Assessment Cycle: Global Warming of 1.5°C, Climate Change and Land, Ocean and Cryosphere in a Changing Climate.
- Compared to previous IPCC reports, WGII AR6 aims to further **develop the emphasis on humans and the societal impacts of climate change, with a strong focus on options for solution pathways at global and regional scale**.
- The report is developed by more than 260 selected experts who bring a diverse range of scientific expertise with **regional, cultural and social perspectives**. Scientists of various disciplines, practitioners, as well as young and indigenous researchers are all included.
- The outline encompasses a total of eighteen chapters, including seven regional chapters, and seven cross-chapter papers which will provide a cross-cutting assessment of regions and systems of particular interest.
- WGII AR6 will be finalized in 2021, in time for the Global Stocktake foreseen under the UNFCCC Paris Agreement.

IPCC Special Report on Climate Change and Land (SRCCL)
Jim Skea, Sigourney Luz, IPCC Working Group III

- The report is the result of work of 107 authors and review editors from 52 countries, with 53% of these contributors from developing countries.
- The **structure of the Special Report** is as follows:
  Chapter 1: Framing and Context;
  Chapter 2: Land-Climate Interactions;
  Chapter 3: Desertification;
  Chapter 4: Land Degradation;
  Chapter 5: Food Security;
  Chapter 6: Interlinkages between desertification, land degradation, food security and GHG fluxes: Synergies, trade-offs and Integrated Response Options;
  Chapter 7: Risk management and decision making in relation to sustainable development.

World Climate Research Programme: Climate Science for Society
Boram Lee, WCRP science community

- The **WCRP Strategic Plan 2019–2028** puts in place a framework to **address frontier scientific questions related to the coupled climate system**. WCRP coordinates and facilitates international climate research to ensure the delivery of sound, relevant and timely climate science towards a more resilient present and sustainable future for humankind. This includes:
    - Fundamental understanding of the climate system
    - Prediction of the near-term evolution of the climate system
    - Long-term response of the climate system
    - Bridging climate science and society
- Implementation of the Strategic Plan is underway and will involve **wide consultation** with the climate science community and partners.
- This year WCRP is also celebrating its **40th anniversary**, including with a special Symposium during the "WCRP Climate Science Week" at the American Geophysical Union (AGU) Fall Meeting (8 December 2019).

An integrated approach to Earth Energy Imbalance
Boram Lee, WCRP science community

- Quantifying exchanges of heat between the different components of the Earth, and assessing energy perturbations to climate system processes resulting from human activities - including forcing and feedbacks - **fluxes are fundamental to understanding the carbon, energy and water nexus; driving ocean circulations, determining how much water is evaporated from the Earth's surface, and governing the planetary hydrological cycle**.
- **Our planet continues to be out of balance** with additional heat being added to it at the rate of $0.6 \pm 0.4\ Wm^{-2}$, and the majority of this excess heat is stored in the oceans. The current **Earth's energy imbalance (EEI) is mostly caused by human activity** releasing heat trapping gases like carbon dioxide. The absolute value of EEI is the most fundamental metric defining the status of global climate change and expectations for continued global warming.
- A WCRP-wide framework for an EEI uncertainty assessment: "The Earth energy imbalance and its implications: Where does the Energy go?" works toward three main overarching goals to:
    - Improve and quantify the absolute value of the EEI;
    - Perform an inventory of the EEI in the Earth system, predominantly for the ocean, land, cryosphere and atmosphere; and,
    - Further increase knowledge on the implications of EEI and associated patterns of climate change, particularly in regions, for the benefit of societies.

GFCS Climate services information system – Regional climate focus including data and products for service delivery
Maxx Dilley, WMO

- The WMO Climate Services Information System (CSIS) uses a **regional approach (CSIS-R) to provide data across scales**.
    - Global forecast models produced by Global Producing Centres (GPCs) feed in to regionally optimized ensembles and verifications in Regional Climate Centres (RCCs)
    - These allow empirical calibration and end-use specific predictands at the national level in National Meteorological and Hydrological Service Centres (NMHSs).
    - Combined with additional global observations and reanalysis, National Climate Outlook forums, and national demand identification and sectoral data, Tailored products can be produced.
    - These products feed back into regional data coherence and monitoring efforts in RCCs and go on to allow global observation and reanalysis which inform the Global Forecast Models.
- CSIS institutions and operational processes are subject to continuing efforts aimed at expanding and improving climate services at country level.

Green Climate Fund climate rationale
Amir Delju, WMO

- **Climate scientific evidence provides a rationale for transformative climate action**. It delineates the value chain through which climate science, data and products inform decisions to effectively address the risks and adapt to a changing climate. It explores the climate science elements of **a GCF climate rationale**, which is applicable to all GCF funded projects and activities.
- In terms of temporal and spatial scales, the climate scientific evidence characterizes the climate of the past, present and future (near and distant), as well as the local, regional and global climate, respectively.

B. Posters on Theme 1: Transformation of energy and other sectoral systems to achieve the purpose and long-term goals of the Paris Agreement[40]

161. Nine posters were presented on theme 1 and are hyperlinked and summarized below.

Macroeconomic impact assessment of the Spanish national energy and climate draft plan (NECP)
Maria Sanz, Basque Centre for Climate Change (BC3)

- A new study shows that the integrated **National Energy and Climate Plan of Spain will generate significant economic, social and health benefits**.
- Recently, all Member States have presented their national energy and climate plans (NECP) for the period 2021–2030.
- The NECP of Spain has been recognized as a **good practice** by the European Commission and by the European Climate Foundation.
- It establishes a reduction of 21% in greenhouse gas emissions by 2030 with respect to 1990, a contribution of renewable of 42% by 2030 and a significant reduction on final energy consumption.
- The impact assessment has used an **integrated set of models and tools** that includes the energy, economic and health nexus. It has been developed in close collaboration with the Spanish Ministry for Ecological Transition and different stakeholders.
- The impact of the Spanish NECP show a significant economic boost. It would generate an increase in GDP between 19,300–25,100 million € per year (1.8% of GDP in 2030) and an increase of net employment by 250,000 to 364,000 jobs/year (+1.7 % in 2030).
- Moreover, the Spanish NECP show a **positive impact for the lowest income households and for vulnerable groups, which is critical to advance towards a just transition**.
- Finally, **public health** will improve substantially and premature deaths will be reduced by 25%.

Research on Enhanced Action and Mitigation Pathways to Keep Paris Goals in Reach
Elmar Kriegler, Heleen van Soest, Detlef van Vuuren, Keywan Riahi, COMMIT and CD-LINKS consortia

- Recent research on **mitigation pathways** towards Paris climate goals has combined global and national model results and looked at different near-term climate action trajectories and their implications for keeping the Paris climate goals in reach.
- **Country specificities play a key role in designing national low-emission strategies**. National-level models capture such specificities and show that strategies depend on policy priorities, domestic energy resources and broad socioeconomic considerations.
- **Nevertheless, key features of the decarbonisation pathways are shared**:
  - Expansion of renewable energy sources for electricity, liquids, and gases.
  - Accelerated energy efficiency improvements in all demand sectors (buildings, transport, industries).
  - Electrification of final energy demand (mobility and heating).

[40] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-7.

- The collective future emissions from the seven largest emitting countries were analysed under two scenarios of progressively strengthened NDCs vs. deeper decarbonization with enhanced action until 2030. It was found that only the latter is compatible with cost-efficient likely 2°C pathways.
- Enhancing **near term action can be achieved by a global roll-out of good practice policies**. It was found that **such a roll-out could narrow the emissions gap** between the collective emissions outcome of proposed NDCs and global CO_2 emissions from cost-effective pathways by ca. 10 GtCO2 in 2030.
- The results presented in the poster are based on the work of the CD-LINKS, COMMIT and PEP1p5 projects.

The role and potential impacts of using Carbon Dioxide Removal to achieve the Paris Agreement goals
David Keller, GEOMAR Helmholtz Centre for Ocean Research

- **Carbon dioxide removal** (CDR) or "negative emissions" is required to reach the 1.5 degree goal and also included in most other well below or equal to 2 degree scenarios. However, **little is understood about implications and impacts of large-scale CDR**. This poster addresses the topic of CDR from an Earth science perspective.
- The Carbon Dioxide Removal Model Intercomparison Project (**CDRMIP**) uses Earth system modelling to **investigate how the climate and Earth system may respond to CDR**.
- Some of the most fundamental natural science questions regarding CDR have not been sufficiently answered, e.g., questions concerning efficacy and side effects.
- The **current generation of Earth system models can simulate only a few CDR methods**, i.e., they lack the capability to explicitly simulate many methods.
- If temperature targets are missed, modelling suggests that many aspects of climate change may be reversible at the global mean level if massive amounts of CDR are used. However, for **most of the system there is a decadal to centennial time lag** before climate change "reverses".
- **Even if global scale properties are reversible, at a local level changes may be irreversible** (after hundreds of years) and the **models lack** some important, potentially irreversible, **components such as ice sheets**.

Decarbonisation or Defossilisation? Innovative Alternative Fuels for the Aviation in Brazil. An international reference model
Jürgen Kern, German Aerospace Center (DLR) Institute of Engineering Thermodynamics

- **Even if global scale properties are reversible, at a local level changes may be irreversible** (after hundreds of years) and the **models lack** some important, potentially irreversible, **components such as ice sheets**.
- Alternative fuels play a significant role in the reduction of climate effects on aviation.
- Synthetic fuels from renewable energy, like Fischer-Tropsch Kerosene (without aromates) are a prefect alternative fuel for the state of the art and future aviation.
- Brazil has:
    - Accelerated energy efficiency improvements in all demand sectors (buildings, transport, industries).
    - Already large markets in decentralized application.
    - Opportunities of advanced developments of its biofuel industry.
    - Good conditions for an expansion of production and use of sustainable aviation fuels with renewable energies (hydro, wind, solar, ...).
- It could be an international reference model for "alternative fuels in aviation."

Building capacities to inform short-term choices toward deep decarbonization
Marta Torres Gunfaus, IDDRI

- To meet the Paris Agreement, it is critical (for implementation and support) that each country develops a clear understanding of its role in the transition and the possible socio-economic impacts, opportunities and challenges. This is the rationale for the Deep Decarbonization Pathways (DDP) initiative.[41]

- The DDP initiative is a collaboration of leading research teams currently covering 36 countries. It encourages the **development and the structuring of a global scientific community of analysts working on the country-based assessment of ambitious climate objectives**, in line with the Paris Agreement.
- The DDP country teams build and bring to the public debate realistic decarbonization pathways to net zero at sector- and economy-wide level, while satisfying socio-economic objectives. This is done country by country to consider in each case the specific context, and highlighting key drivers of the transformation and their potential effects while ensuring consistency with the Paris Agreement long term goals.
- To allow for cross-country comparison in a transparent way, enabling a constructive debate, peer learning and mutual understanding of other countries' strategies to identify useful cooperation areas (e.g. joint R&D efforts), DDP projects use a common dashboard to capture transformation metrics at economy wide- and sector-level. This approach has generated some valuable lessons that could inform the structuring of international debates such as the Global Stocktake.
- This DDP method is designed to be able to contribute to the international debate on global-scale enabling conditions based on consistent country-specific analysis.
- Ultimately the DDP approach aims at supporting the reinforcement of institutional capacity and contributing to their policy debates through in-country development of standard tools, the support to develop or refine detailed models and the structured engagement of stakeholders.

Interlinkages, Investments, Institutions – Energy for the 21st century
Fabian Wagner and David McCollum, International Institute for Applied Systems Analysis (IIASA)

- There are **significant synergies between three aspects of sustainable energy: security of supply, carbon mitigation, air pollution control**.
- In fact, just the **co-benefits on air-pollution** often outweigh the societal costs of even very ambitious GHG mitigation.
    - Co-benefits often accrue at the local or regional level, while delegates often focus just on the national perspective.
    - An extension of work of Economics Nobel Prize winner Bill Nordhaus shows that socially optimal mitigation rates (and implied carbon prices) are much higher when air pollution co-benefits are included. Thus, **co-benefits provide excellent arguments for implementing ambitious climate policies**.
- Some sustainable development goals (SDGs) have reinforcing relationships, whereas others may be in conflict. **Context-dependencies will shape these inter-linkages**.
- While the current climate targets imply negative GHG emissions, deep reductions of non-CO_2 emissions (CH_4, N_2O, F-gases) face **technical limitations**.
- **Behavioral changes (e.g., diets), less food waste and improved agricultural practices could offer additional mitigation potential, which would then lessen the need for negative CO_2 emissions**.

Energy and Sectoral Transition in the Context of the Paris Agreement
Jim Skea, Priyadarshi R. Shukla, Sigourney Luz, IPCC Working Group III

- The long-term temperatire goal of the Paris Agreement imply rapid and far-reaching transitions in energy, land, urban and infrastructure and industrial systems.
- **Research priorities for system transitions** are:
    - Strengthening sectoral decarbonization strategies in the industry, buildings and transport sectors;
    - Representing the financial sector in system models;
    - Role of regulatory financial institutions and their role in underpinning mitigation efforts;
    - Interactions between mitigation responses and sustainable development;
    - Carbon dioxide removal (CDR): responses other than BECCS and afforestation;
    - Emissions reduction potential of behavioural mitigation options;

[41] See http://www.ddpinitiative.org.

    - Enabling change in organizations and political systems;
    - Methods for assessing the contribution and aggregated impact of non-state actors;
    - Land-use planning in cities, especially where tenure and land zoning are contested;
    - Multilevel governance, in particular in developing countries, including participation by civil society, women and minorities

- How can **social science** help?
    - Improved relevance, assessment and communication of existing social science;
    - Integrate complementary insights from different social sciences e.g. psychology, sociology, political science etc.;
    - "Systematic review" of literature;
    - Applied social science to help us understand "what works," e.g. through post-evaluation of policy responses, policy learning;
    - Communicate in a language that policymakers can understand

- IPCC AR6 is attempting to push the envelope with a chapter on demand, services and social aspects of mitigation, piloting systematic review techniques.

Global Energy Transformation: A Roadmap to 2050
Gayathri Prakash, International Renewable Energy Agency (IRENA)

- Based on IRENA's analysis, energy-related carbon-dioxide (CO_2) emission reductions would have to decline **70%** by 2050, compared to current levels, to meet climate goals. A large-scale shift to electricity from renewables could deliver 60% of those reductions; **75%** if renewables for heating and transport are factored in; and **90%** with ramped-up energy efficiency.
- The share of renewables in the world's total final energy consumption has to **increase six times** faster to meet agreed climate goals.
- **Electrification** with renewable power can start to reduce energy-related carbon dioxide (CO_2) emissions immediately and substantially. The pairing is also getting cheaper than fossil fuel-based alternatives, lowers local air pollution and increases health benefits, results in positive socio-economic benefits and will be a key enabler to build a connected and digitalised economy and society. Electrification, when paired with renewables, goes hand-in-hand with **energy efficiency**, resulting in lower overall energy demand.
- With electricity becoming the dominant energy carrier, global power supply could more than double, the report finds. Renewable sources, including solar and wind, could meet **86% of power demand**.
- The energy transformation would boost **gross domestic product (**GDP) by 2.5% and total **employment** by 0.2% globally in 2050. It would also bring broader social and environmental benefits. **Health**, **subsidy** and **climate-related savings** would be worth as much as USD 160 trillion cumulatively over a 30-year period, the report finds. Thus, every dollar spent in transforming the global energy system provides a payoff of at least USD 3 and potentially more than USD 7, depending on how externalities are valued.

Development of Sustainable, Smart, Secure and Safe Society by Comprehensive Research and Development of Gallium Nitride (GaN)
Shugo Nitta, Maki Kushimoto, Manato Deki, Atsushi Tanaka, Yoshio Honda, and Hiroshi Amano, Center for Integrated Research of Future Electronics, Institute of Materials and Systems for Sustainability, Nagoya University, Japan

- Nagoya University and the Institute of Materials and Systems for Sustainability detail the emission reduction potential of using Gallium Nitride (GaN) electronics instead of conventional technologies.
- **GaN based power and high-frequency devices reduce energy loss and are smaller than Si based power electronics**.
- GaN based lighting is an affordable option with low power requirements and can therefore be used to provide light in isolated homes using solar energy.
- Energy savings
    - By using GaN-based LED lightings, 7% of the total electricity consumption can be reduced in Japan by 2020.

    - Total electricity consumption can be reduced by 9.8% by replacing Si-based transistors with GaN-based transistors.

- Contribution to reaching zero emissions
    - Efficiently powered electronics for energy generation, transmission, conversion and consumption is necessary.
    - The Kaya identity implies that decreasing energy intensity of the GDP and the carbon footprint of energy represent priority opportunities to reduce greenhouse gas emissions.

- Societal Transformation
    - GaN-based electronics allow the wireless transmission of energy which enables flexible and intelligent energy supply systems such as the Internet of Energy (IoE).
    - Applications include the use of GaN based solutions to tackle challenges such as age-restricted mobility, commuting services, drone technology, and efficient energy transferal.

C. Posters on Theme 2: Transformative adaptation and climate resilient development[42]

162. Seventeen posters were presented on theme 2 and are hyperlinked and summarized below.

Transformative adaptation in the Asia Pacific region
Andrew Matthews, Asia Pacific Network (APN)

The APN are promoting shared learning for transformative adaptation in the Asia-Pacific Region. Three initiatives are:

- **Initiating Systemic Change**: APN creates the enabling environment for transformative change by promoting system-wide learning, bringing scientists, policymakers and practitioners together to share experience and consider future interventions.

- **From Individual to Collective**: Promoting participatory adaptation and development of community-based tools, to enhance community resilience including regional expert consultation on climate-smart agricultural policies, strategies and programme.

- **Towards Science Based Adaptation Actions**: Climate Adaptation Framework: APN launched a Climate Adaptation Framework in 2013 to enhance science-based adaptation activities in the Asia-Pacific. These activities focus on actionable research and adopt a partnership and integrative approach, many of them look at the linkages between adaptation and disaster risk reduction.

M'Bororo indigenous knowledge for climate adaptation and resilience
Hindou Oumarou Ibrahim, Association of Peul Women and Autochthonous Peoples of Chad

- Indigenous M'Bororo knowledge is a **concrete solution for climate adaptation**: traditional medicine, resilient crops, fresh water sources and weather forecasts.

- Indigenous traditional knowledge is the **heritage of hundreds of years living in harmony with the environment**. Information about the weather can be obtained through: stars observation, bird watching, tree and plant studies and clouds and wind reading

- **Women are major actors** to find solutions for climate change, as, for example in the Sahel, they are the most impacted by climate change. They are affected through: increased time spent collecting water and wood, disappearance of plants used for traditional medicine, difficulties to assure food security for the family, revenue losses that prevent funding for education.

- **3D participatory mapping** enables the gathering of communities in an area to map all natural resources to provide multiple benefits including: identification of natural resources, sustainable management of ecosystems, conflict prevention, transmission of indigenous traditional knowledge.

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[42] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-8.

Global Research and Action Agenda on Cities and Climate Change Science
Boram Lee, CitiesIPCC Partners

- A **Global Research and Action Agenda on Cities and Climate Change Science**[43] has been developed by Cities Alliance, City of Edmonton, C40 Cities Leadership Group, Future Earth, ICLEI-Local Governments for Sustainability, IPCC, Sustainable Development Solutions Network (SDSN), United Cities and Local Governments (UCLG), United Nations Environment Programme, United Nations Human Settlements Programme (UN-Habitat), and the World Climate Research Programme (WCRP).
- The Agenda showcases the breadth of knowledge needed to support decision-makers and urban practitioners. Building on existing knowledge and action, the Agenda aims to **generate greater knowledge in support of practice and decision making** to address climate change in urban areas.
- It highlights **four cross-cutting issues** where there are knowledge gaps related to methodology and understanding**: Systems Approach, Governance and Institutions, Scale and Observation, Data, Modelling and Scenarios at the city level**.
- The Agenda also addresses **six topical knowledge areas** where the availability of more evidence-based knowledge would support practitioners and decision-makers: **Informality, Urban Planning and Design, Built and Blue and Green Infrastructure, Sustainable Consumption and Production, Finance and Uncertainty.**
- It then presents **approaches** to support the implementation of the Research and Action Agenda through strengthening the science practice and policy interface to advance climate action in cities. This Research and Action Agenda serves as a **call for continued collaboration** to develop the knowledge needed to mitigate and adapt to climate change in cities.

The Copernicus Climate Change Service (C3S): Data and tools to support adaptation actions around the globe
Stijn Vermoote, Copernicus

- Co-creation of solutions requires easy, shared, access to high-quality climate data
- Local solutions require tools for transforming data into useful information
- C3S has developed a Climate Data Store that provides easy access on the internet to a variety of high-quality, up-to-date, global datasets about the impacts of past, present and future climate change.
- The Climate Data Store is continually updated with new data based on the latest science, including observations, reanalyses of past observations, seasonal forecasts and climate model projections.
- The Climate Data Store offers tools and expert guidance that make it possible to transform complex climate datasets into useful visual products, such as maps and charts.
- Users anywhere can use data and tools available on the Climate Data Store for their own local needs. C3S can provide user support, training and guidance where needed.
- The C3S website contains many examples that demonstrate the potential of the Climate Data Store in supporting adaptation in different industrial sectors and regions of the world.[44]
- User engagement is essential to improve the system.

Building Climate Resilience through Engagement with Farmers, Communities, and Youth
Allison M. Chatrchyan, Danielle Eiseman, Cornell University, USA

- The Cornell Institute for Climate Smart Solutions (CICSS) conducts interdisciplinary research, builds stakeholder capacity, and works toward a future where agricultural, environmental, and social systems are resilient in the face of a rapidly changing climate and have reduced their impacts on the climate system. This includes through:
    - **Climate smart farming;**
    - **Climate smart communities;**

[43] See https://citiesipcc.org/beyond/global-research-and-action-agenda-on-cities-and-climate-change-science.
[44] See https://climate.copernicus.eu/global-showcases.

- **Youth education and climate literacy;**
- **Extension and partnerships**.

- **Further social science research is needed** with farmers, community members, and youth, across regions and countries, to better understand how stakeholders are being impacted by climate change, the actions they are taking to respond, and the **policies needed to support sustainable and resilient behavior**s.

Limits to climate change adaptation: New evidence and insights
Johanna Nalau, Griffith University, Australia

Limits to climate change adaptation was recognised in the IPCC 5th Assessment report[45] as an area where there are significant gaps in knowledge. A limit to adaptation is often described in the literature as a point of no return where an actor faces intolerable risks to his or her objectives.

- Adaptation Limits are dynamic and interacting: impacts of the biophysical limits for example give rise to socio-cultural and psychological limits.
- Many communities are facing hard limits and are already on the move in Fiji, Solomon Islands, Papua New Guinea, and Bangladesh; biophysical limits (inundation) are leading to further socio-cultural limits (lack of land tenure, loosing access to culturally important resource maintain reciprocity).
- Historical political commitments create further socio-cultural and political limits to what adaptation can look like due to existing land-use planning regimes.
- **Limits of imagination (what future can be) impact adversely on the kinds of decisions that people and organisations are willing to take and what they think is possible in terms of adaptation**.

Key questions for policy and research:

- **What are the connections between Adaptation Limits and Loss and Damage?**
- **How can we better identify in advance when adaptation limits are about to emerge?**

Ecosystem-based adaptation (EbA): A review of the constraints
Johanna Nalau, Griffith University, Australia

Ecosystem-based Adaptation (EbA) uses ecological processes and systems to help communities to adapt to the impacts of climate change. EbA is a relatively new approach in climate adaptation although ecosystem-based approaches have a long history in conservation. EbA is constrained by multiple factors that all contribute to difficulties in implementation. The main constraints facing EbA as a strategy for climate adaptation include:

- Social and Cultural constraints: differing risk perceptions, landscape preferences and differential access to climate information based on gender
- Governance and Institutional: EbA is often constrained by disagreements on land rights and land tenure issues, while its governance is not matched with jurisdictional boundaries.
- Economic and Financial: high land prices, focus on investing in conservation but not restoration.
- Knowledge: strong emphasis on current but not future climate; heavy reliance on mostly Western knowledge; people do not agree what even EbA means.
- **Knowledge gaps: Monitoring and Evaluation (M&E) still in progress; lack of understanding when EbA is limited in its capacity to deliver the expected benefits; negative impacts arising from EbA projects not well understood.**
- **Physical and Biological: ecosystems already degraded so EbA is not starting from optimal baseline; biophysical limits on what species can do under a changing climate**.

Healthy Urban Microbiome Initiative: A Pathway to Climate-Resilient Future
Chris Skelly, Healthy Urban Microbiome Initiative

- The Healthy Urban Microbiome Initiative (HUMI) aims to **integrate recent developments in microbiome science into a population health approach that delivers sustainable and biodiverse urban green space for health improvement**.

[45] IPCC AR5 Chapter 16, Klein et al., 2014.

- The HUMI is modelled on a place-based population health approach and is science-led, community-focused and enabled by civic-leadership. It includes scientists, local government and public health professionals working in partnership with community-led groups to improve the health of our populations and environment.
- The project supports sustainable development goals: 3, 10, 11, 13, 15 and 17.
- The Secretariat for the Convention on Biological Diversity and HUMI have partnered to **improve population health through the restoration and creation of biodiverse urban green space** around the global.

Scaling up local actions in support of Paris Agreement: A guide for local and sub-national governments
Maryke van Staden and Pourya Salehi, ICLEI - Local Governments for sustainability

- To successfully implement the NDCs as outlined under the Paris Agreement, **cities need to be able to address the growing contribution of global greenhouse gas emissions from expanded urbanization, while simultaneously adapting to the increased risk associated with climate change**.
- The **Solutions Gateway** acts as a **translation of peer-reviewed research into concrete, applicable solutions** for cities to implement low-emission, resilient, and sustainable development strategies.
- Using the guidance within this platform, cities are able to learn from and replicate **successful examples and solutions** to increase climate adaptation and mitigation in sectors such as energy, transport, infrastructure, water systems, and waste management.
- With exemplary cases and thorough workflow processes to support these energy and sectoral system transitions, **cities are provided with the necessary tools and resources** to decrease greenhouse gas emission in accordance with national targets under the Paris Agreement.

Transforming coastal-marine governance in the face of climate change
Jeremy Pittman, Inter-American Institute of Global Change Research (IAI) and University of Waterloo, Canada

- Transformative adaptation inherently involves working across multiple governance levels, and it can involve transforming multilevel governance systems themselves in order to achieve the desired outcomes for communities and ecosystems
- **Our poster demonstrates empirically how these processes of governance transformation occur and how social networks at the community-level influence or moderate how transformative processes take place**.
- Specifically, we examine how the **effects of governance transformations** aimed at empowering small-scale fishing communities in decision making (i.e., the implementation of a co-management regime) are **moderated by local social networks** among the fishers, which affects how key structural variables (age, gender, family group) influence individual fishers' empowerment in the co-management regime.
- Our work shows empirically the **importance of considering community-level social networks** when attempting transformative adaptation in multilevel governance systems.

A Case Study: Adaptation Measures for Extreme Floods in Japan, Using Huge Ensemble of High-resolution Climate Model Simulation
Tomohito Yamada, Associate Professor, Faculty of Engineering, Hokkaido University, Japan

- The poster shows how the research group have applied thousands of dynamical downscaling both for past and future climate conditions and estimated extreme conditions for precipitation. This approach allows **prediction of future changes in precipitation extremes** because extremes have also occurred in the past but with a lower probability. With this knowledge, it is possible to plan future flood control policy based on the probability of extremes.
- According to previous results**, risks of disasters by heavy precipitation will be higher in the future**. However, there are many types of risks in our life. **Decisions need to be based on universality of values/priorities of risks/benefit of all kinds of factors which affect human life**.

- The study showed that extreme precipitation will be stronger in future climate condition in addition to more intense both in temporal and spatial scales. It means that **damage due to heavy precipitation will be more severe**. **Flood control in future needs to be discussed** not only in **each river basin scale** but also in **regional scale** (community scale). In addition, **studies for risk/benefit assessment that incorporate various types of topics/targets are needed to revitalize the community**.

Intellectual Capacity Building for a Climate-Resilient Future: the New Humanism Approach
Gaston Meskens and Silke van Cleuvenbergen, New Humanism

- Transformative adaptation and climate resilient development requires **intellectual capacity building that enables us to deal with climate change as a complex social problem** while caring for sustainability, selfcare, autonomy, equity and solidarity.
- Climate change as a complex social problem implies that **we are connected with each** other 'in complexity'. We cannot any longer escape or avoid it. Fair dealing with each other implies a fair dealing with the complexity that binds us.
- The fact of connectedness is not a challenge but an opportunity for humanity, but it requires an intellectual capacity that concerns and benefits us all: **ethical competence**
- **Innovations in social sciences and humanities can help achieve and manage the necessary social and cultural changes and political reform** towards building joint ethical competence.
- Ethical competence is acquired through dialogue in deliberation, research and education. Education is at the basis of ethical competence
- We need to find~ new structures ~ new forms ~ find solutions beyond comfort zones. Not towards new fixed systems but towards a constantly reinventing fluid society.

Climate Change Impacts and Adaptation for Transport Networks and Nodes
Lukasz Wyrowski and Martin Dagan, United Nations Economic Commission for Europe (UN-ECE)

- **Transport networks and nodes are key to** facilitating people and goods **access to markets**; disruptions on these networks or at nodes can negatively affect this access, and can impact economic development as well as well-being of people;
- **Extreme weather events**, increasing in frequency and severity due to climate change, may and will **cause disruptions on networks and at nodes**;
- **Specific and cost-effective adaptation measures are necessary**; such can be defined and designed if impacts on transport infrastructure can be assessed;
- UNECE with support of WMO and partners, within a UNECE Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes, analysed **six indices, as proxies to assess potential impacts** from temperature and/or precipitation- related extreme events on transport networks and nodes;
- This work gives **first indication of potential areas that may be affected in the future by highest absolute increases in events as assessed with the proxy indices**; matching these change maps of the climate indices with the infrastructure data gives a first indication on the sections of networks and nodes that are located in areas exposed to highest absolute changes and which may be exposed to increased risks in the future;
- **More analysis and research is necessary** to assess climate impacts on transport infrastructure and operations;
- **Efforts should be devoted to obtaining consistent projections data set for entire regions**, e.g. covering entire transport corridors, such as e.g. inland corridors between Europe and Asia, so that data along entire corridors can be comparable;
- **Climate indices and/or set of climate indices should be defined** to analyse the impacts of extreme events on transport infrastructure and operations as accurate as possible;
- Indices related to analysing **wind-related extreme events should be further researched**.

The role of communities´ perception in adaptation. An agency approach to understand adaptive capacities related to changes in water availability in El Aguacatemicro-watershed (Paz River, El Salvador)
Blanca Liliana Narvaez Marulanda, Fabrice Renaud, Zita Sebesvari, United Nations University Institute for Environment and Human Security (UNU-EHS)

- In order to manage the **social, economic and cultural challenges that communities face** when they strive for adaptation and climate resilient development, **individual (agents) need to be aware of their own progress and limitations** dealing with adverse impacts of climate variability.
- This poster summarizes the **highlights of a research conducted in a mangrove area in El Salvador** where several ecosystem-based adaptation strategies have been implemented during the last ten years.
- We applied an **agency approach by focusing on key cognitive elements** such as social identity, knowledge, motivation and learning process.
- The case study **demonstrates the value of such an in-depth analysis and shows that considering communities´ perception is advantageous**, because it helps to understand the decision-making dynamics that will lead (or not) the respective agents to undertake action for the implementation of adaptive strategies at the local level.

Monitoring of and reporting on green infrastructure in the Sendai Framework Monitor: relevance for adaptation
Zita Sebesvari, Yvonne Walz, Blanca Liliana Narvaez Marulanda, UNU-EHS

- One of the key challenges to achieve "transformative adaptation and climate resilient development" is the coherence among the different domains of the Post-2015-Agenda. Potentials for synergies are not fully tapped.
- **Resilience and ecosystem-based solutions have been identified as areas with great potential to support synergies effectively**.[46] Progress in the implementation of ecosystem-based adaptation and ecosystem-based disaster risk reduction will support climate resilient development. If these measures are considered as part of the overall adaptation and disaster risk reduction strategy, countries might wish to report progress of implementation as well as losses due to disasters.
- The poster showcases that **using already existing reporting options in the Sendai Framework Monitor (SFM) for disaster related losses of green infrastructure can help to generate baseline information for the global stocktake**.
- The concepts of critical and **protective green infrastructure** (GI), as discussed in the SFM, **is helpful to identify the potential synergies between reporting losses related to ecosystems (e.g. wetlands) and the monitoring of progress made in adaptation** in the context of climate related hazards (e.g. floods and droughts).
- The poster uses a **case study of wetlands in Colombia to provide context** to the discussion of synergies between disaster risk reduction (DRR) and climate change adaptation (CCA) based on wetlands.

Interactive Story map for infrastructure impacts under different scenarios in the Seychelles
Harold Rice, Brett Rolf, Jacob Rumschlag, Daniel Xie, University of Michigan, USA

- The objective of this project was to **narrow adaptation knowledge gaps regarding the impacts of sea level rise (SLR) and storm surge on the critical infrastructure of the Seychelles**.
- Methods used: Interviews identified critical infrastructure, existing adaptation action, barriers to adaptation, and what further adaptation action is needed. GIS analysis involved mapping risk presented by SLR and storm surge.

[46] UNFCCC (2017). Opportunities and options for integrating climate change adaptation with the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction 2015–2030. See https://unfccc.int/sites/default/files/resource/techpaper_adaptation.pdf.

- Interviews indicated that **one key challenge is there is little understanding that climate change poses a genuine threat despite a general acknowledgement that it is happening**. An in-depth education on the issue is lacking.
- **Results of GIS analysis were incorporated into an ESRI story map**, which can be useful for providing information of climate change impacts to a broad audience. The **ability for viewers to focus in on places of relevance to them may make the threat of climate change more salient** to them than conventional, static figures do.

CORDEX CORE: Coordinated Output for Regional Evaluation
Chris Rennard, Irene Lake, Bill Gutowski, Silvina Solman, WCRP CORDEX Science AdvisoryTeam

- The **CORDEX-CORE ensemble will provide the basis for an assessment of future extreme events** for all major inhabited regions of the world.
- An **ensemble of high-resolution** (~25km gridbox-size) **regional climate change information is created and presently being evaluated**.
- The CORDEX-CORE ensemble will **provide the basis for an assessment of future extreme events for all major inhabited regions of the world**.
- Further analysis for different global warming levels, e.g., +1.5C or +2.0C will be performed based on the CORDEX-CORE ensemble.

D. Posters on theme 3: Changing levels of risk and the attribution of extreme climate events and impacts to climate change[47]

163. Seven posters were presented on theme 3 and are hyperlinked and summarized below.

Weather-related hazards and population change: A study of hurricanes in the US, 1980–2012
Elizabeth Fussel, Brown University, USA

- Environmental determinists predict that people move away from places experiencing frequent weather hazards, yet many of these areas have rapidly growing populations. This poster shows the **relationship between hurricanes and tropical storms and population change** in all U.S. counties that experienced one of these events between 1980 and 2012. Findings are:
  - Population growth trends in counties affected by hurricanes are heterogeneous.
  - Counties' past growth is the strongest predictor of future growth, but the direction of effect differs.
  - Hurricane effects are only statistically significant in high density counties with growing populations, but the direction of effect is not uniformly negative.
- **Policy makers cannot assume that hurricanes, and by extension other extreme weather events, have uniform effects on population growth trends**. Pre-event population growth trends condition future growth after a hurricane. Growing urban places that have high cumulative hurricane-related losses may experience higher future growth because of investments in recovery and adaptations to risk.

Knowledge Action Network on Emergent Risks and Extreme Events (Risk-KAN)
Markus Reichstein, Jana Silmann, Dorothea Frank and Boram Lee, Future Earth- Integrated Research on Disaster Risk (IRDR) - WCRP, RISK KAN Development Team

- Climate impacts result from weather and climate extremes, understanding past changes in weather and climate extremes allows understanding of emergent risks.
- **Despite the major advances in extremes research, there are significant challenges to meet society's adaptation needs** to:
  - Enhance the monitoring network and capabilities;
  - Continuously improve the understanding and simulation of the processes leading to extremes of different spatial and temporal scales and to develop innovative communication solutions between climate research and its user communities.

[47] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-9.

- WCRP, Future Earth and IRDR works together in developing the Knowledge Action Network on Emergent Risks and Extreme Events[48] (Risk KAN) toward the **better interaction and cross-community collaborations between the research and risk management communities**. Building on the bottom-up initiatives by the risk-extremes research community, the **Risk KAN is developing its workplans to exchange information, knowledge and data, and to co-define a collective scientific focus beyond any single partner**.
- Risk KAN welcomes contribution to and participation in further development of KAN structure, Working Groups and others. We look forward to new participation!

ISIMIP & ISIpedia - Inter-sectoral impact modeling and communication of national impact assessments
Katja Frieler, Iliusi Vega, Potsdam Institute for Climate Impact Research (PIK)

- ISIMIP is an international initiative of climate-impact researchers who contribute with more than 130 **harmonized global- and regional climate model simulations data sets**, to quantify cross-sectoral climate impacts under different levels of global warming relative to pre-industrial conditions.[49]
- Climate impact results depend on climatological events as well as on human factors (e.g. land-use patterns, water management and use of fertilizers), which complicates attribution.
- We **provide a systematic quantification at the national and global level of the purely climate-induced changes in land area affected by, and the number of people exposed to, extreme events for 1°C (historical), 1.5°C and 2°C global warming**.
- ISIMIP do this by comparing scenario simulations against no-climate-change baseline simulations.
- Extreme events cover six well-defined categories: river floods, tropical cyclones, wildfires, crop failure, drought and heat waves (Lange et al., under review).
- These **impacts results are gathered into country-specific assessments via relevant indicators** within the framework of the ISIipedia project, in close cooperation with regional stakeholders and decision-makers. These are sorted according to the type of study into: future projections, attribution studies (which are the already observed changes that are due to climate change?), model evaluation (how confident are we that our models describe the most important processes well?), or country.
- ISIipedia assessments are made accessible on an **interactive online platform** with the aim of reaching a wide public and contributing to policy advice.[50]

Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of SIDS
Regina Asariotis, United Nations Conference on Trade and Development (UNCTAD)

- **Many SIDS lack baseline data.** Infrastructure inventories, higher resolution data, including better Digital Elevation Models (DEMs), as well as a better understanding of coastal processes under climate change are required for effective risk-assessment and adaptation planning. Detailed technical studies at facility level (multi-hazard risk-assessment) are required to avoid maladaptation;
- Results suggest that **technical adaptation measures are widely needed**. These should **involve innovative and efficient designs to avoid over-engineering**;
- In this context **increased capacity building and investment in local/regional human resources and skills** (in particular highly skilled coastal scientists/engineers) will be critical for successful adaptation and resilience building in the future;
- **Financing for technical studies and for capital projects remains a major hurdle**;
- **Ecosystem enhancements can play a significant role** in reducing natural hazard risks, including coastal hazards and inland flooding.

[48] See http://www.risk-kan.org.
[49] See https://www.isimip.org/.
[50] See https://www.isimip.org/isipedia.

Understanding convective extremes and related phenomena under changing climate conditions
Bill Gutowski and Silvina Solman, WCRP CORDEX Science Advisory Team

- Several Flagship Pilot Studies on high-resolution, convection permitting, coupled Regional Climate Models, as well as statistical downscaling methods, are ongoing in Africa, South America and Europe/Mediterranean.
- The scientific aims are to **understand processes and phenomena relevant for regional climate change**, to combine information from different sources, to evaluate/compare methods, to assess multi-model ensembles, to estimate future evolution of extremes, to understand sources of uncertainty and much more.
- The **societal aims are to establish confidence in simulated changes, tailor information for impacts assessments/decision makers and to communicate findings in an actionable manner**.

Quantifying the evidence on environmental migration: A meta -analysis on country level studies
Roman Hoffmann, Wittgenstein Centre for Demography and Global Human Capital

- Climate change is expected to have **major impacts on human mobility** with implications for origin and destination regions. Growing academic and political interest in the topic. Despite an increasing number of studies, there is no scientific consensus to what extent and under which conditions environmental factors influence migration.
- This study represents the **first meta-analysis** of the topic synthesizing the evidence from 30 country-level studies, which estimate the effect of gradual environmental change and rapid-onset disasters on internal and international migration worldwide.
- Environmental factors are found to affect migration, but the strength and direction of the relationship crucially depends on the study contexts and background.
- **Temperature changes and rapid-onset events have the strongest effect on migration outcomes.** The effects are most pronounced shortly after the event and fade over time.
- The **strongest relationship between environmental factors and migration is found in studies focusing on Latin America and the Caribbean**, followed by studies focusing on the Middle East and North Africa and East, Southeast, and South Asia.
- Our results indicate that **middle-income-countries have the strongest environmental migration response**. Contrary to common beliefs, country-level studies focusing on Sub Saharan Africa do not find consistent evidence for environmental migration, but rather the opposite. One explanation for this result is that **populations in low-income countries are often more restricted in their migration**. This effect might be amplified under environmental stress, potentially resulting in 'trapped populations'.
- **Conflicts are found to potentially amplify the effects of environmental shocks on migration**. At the same time, confirming recent findings in the literature, we find evidence that conflicts may be one of the mechanisms through which environmental change affects mobility.
- **Given the likely future changes in environmental conditions** in many parts of the world, **our findings have important implications for the impact of anthropogenic climate change on populations**.

Changing levels of risk and the attribution of extreme climate events
Blair Trewin, WMO

- WMO has defined a set of standard **State of the Climate indicators** for tracking various aspects of climate change.
- Increasingly, human activity is being found to have an impact on the risk of extreme climate events. **88 out of 128 peer-reviewed papers published about extreme events in the period from 2013 to 2017 found a human influence on the risk of that extreme event**. This includes examples such as the effect of human activity in increasing the rainfall in tropical cyclones such as Hurricane Harvey, which caused extreme flooding in Texas in 2017.
- **Extreme climate events often have major impacts, whether in terms of casualties, displaced people, or economic losses**. Heatwaves are particularly hazardous to human health and are affecting an increasing number of people.

- **2018 had a broad range of extreme climate events**, including extreme heat and drought in northern Europe; extreme flooding followed by heatwaves in Japan; major flooding in southern India; the first category 5 hurricane landfall in the mainland United States since 1992; drought in eastern Australia, Argentina and Uruguay; and the most destructive wildfire on record globally in terms of economic loss, in California.

E. Posters on theme 4: Role of the ocean in the climate system[51]

164. Nine posters were presented on theme 4 and are hyperlinked and summarized below.

Global Synthesis of the Response of Marine Taxa to Ocean Acidification
Katja Mintenbeck and Hans Otto Pörtner, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)

- Anthropogenic carbon dioxide (CO_2) emissions cause the partial pressure of CO_2 (PCO_2) to rise in the atmosphere and the oceans, resulting in shifts in ocean chemistry including its **acidification**.
- Climate-related **ocean acidification affects marine species and ecosystems in different ways**, adding to the impacts of ocean warming and deoxygenation.
- A **meta-analysis of the impacts of ocean acidification** on marine species was carried out in the framework of the German research network BIOACID (Biological Impacts of Ocean Acidification). The study elucidates and assesses the responses of almost 500 different species from more than 650 published studies at different PCO_2 levels.
- The analysis of the data shows that the **amount of negatively affected species increases with increasing ocean acidification in all investigated animal taxa**, but sensitivity to different levels of PCO2 differs between taxonomic groups.
- **Calcifying groups**, in particular some macroalgae, molluscs (gastropods and bivalves) and echinoderms (e.g. sea urchins) but also **corals**, **are particularly sensitive**, while non-calcifying macroalgae and some microalgae may benefit from increasing carbon dioxide concentrations and ocean acidification.

Climate vulnerability of fish populations: Integrating lifecycle bottlenecks and emission scenarios
Flemming Dahlke and Hans Otto Pörtner, AWI

- Estimating the climate vulnerability of fish populations requires knowledge of the most sensitive life stages and how stage-specific thermal sensitivity varies across geographic regions.
- In this **meta-analysis**, stage-specific thermal sensitivity is investigated based on the temperature dependence of metabolic rates (thermal reactivity) and the temperature range an organism is able to tolerate (organismal thermal tolerance).
- **Climate impact risks are assessed globally by linking estimated heat tolerance margins with projected warming scenarios**. In addition, potential benefits of limiting global warming to 1.5°C above preindustrial are demonstrated for an Arctic keystone species (Polar cod, Boreogadus saida).
- **Thermal reactivity is higher in embryos than in adults**, varies according to climatic region, and is generally higher in "stenothermal" species with narrow habitat temperature ranges.
- **Spawners and embryos of polar and tropical species are more vulnerable** to warming than temperate ones.
- **Globally, the portion of potentially affected species could be reduced from more than 50% to less than 10% if global warming is limited to 1.5 °C above preindustrial.**
- Meeting the 1.5°C goal could also minimize impact risk for endangered species like Polar cod.
- **Physiology-based habitat models represent an important tool not only for climate risk assessments, but also for identifying potential refuge habitats that should be prioritized in conservation**.

[51] See https://unfccc.int/topics/science/workstreams/research/research-dialogue/eleventh-meeting-of-the-research-dialogue-science-for-transformation#eq-10.

Observing the role of the oceans in the climate system
Simon Eggleston, Global Climate Observing System (GCOS)

- The oceans ameliorate the impacts of climate change by absorbing over 90% of the increased energy in the climate system and 30% of the human emitted CO_2. However, this does have impacts on the oceans: ocean temperature, stratification and acidity deoxygenation and ice loss are increasing.
- Sustained observations are key in monitoring these effects and how they are changing. GCOS works with WCRP and the global climate research community to define the Essential Climate Variables (ECV) that need to be monitored.
- The IPCC Special Report on 1.5C Report identifies 4 global tipping points of concern – all are related to the Oceans. There is a medium risk of at least one of these occurring at temperature increase of 1C and a high risk at 2C
    i. **The cryosphere: West Antarctic ice sheet, Greenland ice sheet**: A global temperature increase of between 1.5ºC and 2°C may initiate irreversible loss of the West-Antarctic and Greenland ice sheet with an increase in sea level rise between several tenths of a meter to 1–2 m. (*ECVs include Ice sheets and shelves, Glaciers, Sea Ice, Temperature and Albedo*)
    ii. **The thermohaline circulation:** slowdown of the Atlantic Meridional Overturning Circulation (AMOC). It is more likely than not that the AMOC has been weakening recently. It is **Very likely** that the AMOC will weaken over the 21st century. (*ECVs include Ocean Temperature, Salinity, and Currents, Ice sheets and shelves, Glaciers, Sea Ice*)
    iii. **El Niño-Southern Oscillation (ENSO):** The frequency of extreme El Niño events increases linearly with the global mean temperature and may double (one every ten years) with 1.5°C of global warming. (*ECVs include Sea Level, Ocean Surface Stress, Heat Fluxes, Temperatures, Salinity and Currents*)
    iv. **The role of the Southern Ocean in the global carbon cycle:** The Southern Ocean have a critical role of as a net sink of carbon which might decline under global warming. (*ECV include Inorganic Carbon, Atmospheric CO_2, Anthropogenic CO_2 Fluxes, Ocean Temperature, Salinity and Currents*).

Blue carbon: Science developments of relevance to the UNFCCC
Kirsten Isensee, Katherina Schoo, and Salvatore Aricò, Intergovernmental Oceanographic Commission (IOC)

- Currently, **for a blue carbon ecosystem to be recognized for its climate mitigation value** within international and national policy frameworks it is **required to meet the following criteria**:
    - Quantity of carbon removed and stored or prevention of emissions of carbon by the ecosystem is of sufficient scales to influence climate.
    - Major stocks and flows of greenhouse gases can be quantified.
    - Evidence exists of anthropogenic drivers impacting carbon storage or emissions.
    - Management of the ecosystem that results in increased or maintained sequestration or emissions reductions is possible and practicable.
    - Management of the ecosystem is possible without causing social or environmental harm.
- **When vegetation is removed** and the land is either drained or dredged for economic development, (i.e. mangrove forest clearing for shrimp ponds, draining of tidal marshes for agriculture, and dredging in seagrass beds—all common activities in the coastal zones of the world), **the carbon in the sediments is released into the atmosphere and ocean**.
- Not only do **these activities result in CO_2 emissions** but they also result in **losses of biodiversity and critical ecosystem services**.
- **Managers** of coastal ecosystems are increasingly **interested in assessing and monitoring carbon** stocks and changes in carbon stocks over time.
- **Blue carbon now offers the possibility to mobilize additional funds and revenue** by combining best-practices in coastal management with climate change mitigation goals and needs.

A 'stressed' ocean: mitigation and adaptation possibilities applying ecosystem-based management
Salvatore Aricò, IOC

- **There is a need to:**
  - **Better understand the links between ocean physical and biogeochemical variability and the** impacts of multiple stressors (e.g., warming, ocean deoxygenation and acidification) on GHG sources and sinks.
  - Combine GHG measurements in regions especially critical for GHG fluxes (the polar oceans, coastal and marginal seas, and coastal upwelling zones) with relevant biogeochemical measurements (e.g., oxygen, nutrients) to su**pport GHG data analyses and model simulations**.
  - Undertake future experimental research efforts to exploit 'natural laboratories' (e.g., in regions of distinct biogeochemical gradients such as ocean eddies, or following climate and ecosystem perturbations induced by volcanic eruptions) to **investigate the response of marine GHG flux changes to multiple environmental stressors**.
  - Elucidate further the **processes of the microbial and biological pumps** in both coastal areas and the open ocean and to assess how these may be affected by anthropogenic stressors such as pollution in coastal areas and by ocean warming.
- Reducing pressures on ocean ecosystems due to human induced stressors will **enhance ecosystem functioning** including in terms of carbon absorption and storage.
- Solutions related to mitigation include **healthy blue carbon ecosystems**; and clean coastal waters.
- Promotion of **literacy** about the causes and effects of multiple ocean stressors will encourage all stakeholders to adopt a more responsible and informed behavior towards the ocean and its resources.
- One of the Strategic Objectives of the **UN Decade of Ocean Science for Sustainable Development** (2021–2030) is "Understanding the effects of cumulative stressors on ocean systems including the socio-economic dimension". The Decade provides an opportunity to communicate widely about the science of multiple stressors and related cumulative impacts.

Acceleration of Ocean Acidification in the Western North Pacific
Toshinori Aoyagi presented on behalf of Hisashi Ono, Japan Meteorological Agency (JMA)

- Over the past 35 years since early 1980s, the Japan Meteorological Agency (JMA) has been conducting shipboard measurements of CO_2 in the ocean and in the atmosphere at 3°N through 34°N along 137°E in the **western North Pacific**. The result of these measurements demonstrates that the **total dissolved inorganic carbon (DIC) has been increasing and ocean acidification has been occurring** in the upper layer of the ocean owing to the uptake of anthropogenic CO2. In addition, the rates of DIC increase and ocean acidification have been accelerating in the surface layer of the subtropical zone at 26°N–30°N. **The rate of pH decreases for the recent 10 years** (2007–2017) **was approximately 1.4 times as large as that for the entire period of measurements** (1983–2017).
- One of the main roles of the ocean is considered to be a sink of CO_2 and thus to contribute to the global warming mitigation. We do not know well at this moment about any kind of tipping points on the role of the ocean. However, **if ocean acidification progresses further, we can imagine the efficiency of the CO_2 uptake may lower, and as a result, increase of atmospheric CO_2 could be accelerated.**
- Saving seaweeds in the coastal zones is thought to be important because they fix carbon in their body as same as forests in the land area do. Also, seaweeds have to be saved for fisheries resources, naturally. Concerning the ecosystems, some reports show that ocean acidification may make the coral calcification speed lower. **Monitoring the coastal ecosystems, such as seaweeds and phytoplankton, could be made by satellite-based observations**, for example the chlorophylls and ocean colors. However, **monitoring of the ocean environment**, like acidification which affect directly to lives in the coastal ecosystems, **can only be made by in-situ measurements of shipboard and profiling float based observing systems. We believe that sustainable maintenances of such basic observing systems have to be paid attention**.

Ocean-Climate Solutions: moving from science to action
Anna Zivian, Ocean Conservancy / Ocean-Climate Platform

- Scientific overview: The ocean has absorbed over 93% of excess heat and over 25% of anthropogenic CO2, with negative consequences on ecosystems and human communities. The latest research from the IPCC 1.5 report, the US 4th climate assessment, and other publications indicates that these **changes are happening ever faster and that without significant reductions in carbon emissions, irreversible changes in ocean ecosystems cannot be avoided**.
- Role of the ocean: Key changes include ocean acidification, ocean temperature increase, deoxygenation, and cumulative effects of these. Potential tipping points include radical food web shifts or collapse due to shifting species, increased ice melt, and sea level rise.
- Ocean-climate actions:
    - Solutions for **adaptation** include **nature-based solution**s (protecting and restoring natural habitats); well-sited, representative, and connected networks of **Marine Protected Areas**; and **climate-ready fisheries management**.
    - Solutions for **mitigation** include **reducing CO2 emissions** from shipping; renewable ocean energy (well-sited through transparent, science based, processes involving stakeholders and the public); and **protecting and restoring coastal ecosystems** for multiple benefits, including carbon sequestration in “blue carbon” habitats.
- **Policy, science, and governance recommendations**: Improving integration of natural and social sciences; connecting scientists, stakeholders, decision makers, and the public around political and policy processes; engaging youth and underserved/underrepresented communities; developing multi-stakeholder partnerships; supporting globally coordinated, sustained, integrated ocean observations; improving ocean literacy and education; and establishing innovative ocean-climate finance systems.

Future sea-level change: Lessons from the past
Marie-France Loutre and Sarah Eggleston, Past Global Changes Science Community (PAGES)

- What impact will a warming climate have on future sea level? Studying the Earth during past warm periods can shed light on what we might expect in the future.
- Sea level, temperature, and atmospheric CO_2 during warm periods of the past Paleoclimate reconstructions show that the **Pliocene** (3,000,000 years before present) and the **Last Interglacial period** (125,000 years before present) w**ere as warm or warmer than today, and sea level was also higher than present**.
- However, while atmospheric **carbon dioxide levels were similar to today during the Pliocene**, they were **lower during the Last Interglacial**. These two well-studied past periods could be used as possible analogues for future sea-level change. Depending on future CO_2 emissions, the atmosphere may warm significantly by the end of this century. **While sea level is not expected to rise immediately to the level of the high-stand during the Pliocene or the Last Interglacial, the rate of increase in 2100 CE is expected to be much larger than today**. This could have important implications for sea level beyond 2100 CE.

Why the Southern Ocean matters
Chandrika Nath and Eoghan Griffin, Scientific Committee on Antarctic Research (SCAR)

- **The Southern Ocean influences ocean circulation and climate on a global scale, but is one of the least observed and least well-understood of the world’s oceans.**
- **The Southern Ocean has slowed the pace of atmospheric warming to date**, by absorbing significant amounts of heat and carbon from the atmosphere. **However, this has caused it to warm and acidify.**
- Ocean warming is in turn linked to the **loss of ice from the Antarctic Ice Sheet**, particularly in parts of **West Antarctica** where glaciers are thinning, speeding up and retreating, **contributing significantly to global sea level rise.**
- The **Antarctic Ice Sheet is also sensitive to changes in sea-ice** (ice that forms on the ocean).
- SCAR facilitates international research to deepen our understanding of the Southern Ocean, how it could respond to future climate change, and what the means for the stability of the Antarctic Ice Sheet, global climate, and sea level.

- Examples of work by SCAR groups includes furthering knowledge of how the Antarctic Ice Sheet responded to climate change in the past, modelling future changes to the ice, atmosphere and ocean, and investigating ocean acidification.
- SCAR and the Scientific Committee on Oceanic Research (SCOR) also co-sponsor the **Southern Ocean Observing System (SOOS), which plays a key role in addressing gaps in observation and measurement**.