CEC '17 Critical Global Discussions

Climate Engineering Conference 2017
Critical Global Discussions
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IASS POTSDAM

Climate Engineering Conference 2017

CRITICAL GLOBAL DISCUSSIONS

Conference Report

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Climate Engineering: Risks, Challenges, Opportunities?

Springer

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Introduction

Building on the success of the first international, inter- and transdisciplinary Climate Engineering Conference in 2014 (CEC14), the Climate Engineering Conference 2017 (CEC17) again provided a platform for critical global discussions by bringing together representatives of the research, policy and civic communities to discuss the highly complex and interlinked ethical, social and technical issues related to climate engineering. Spanning three days and a total of 38 sessions of various formats, the conference allowed participants to gain a thorough and timely update on the latest developments in the field, enjoy vigorous exchange and engage in creative discussions.

Taking place between the first Gordon Research Conference on Solar Climate Geoengineering in Maine in July and the COP23 in Bonn in November 2017, the conference was ideally timed to reflect upon the state of climate engineering knowledge and its significance to the Paris Agreement, with its ambitious temperature and CO_2 emissions targets. Discussion of the possible role of some climate engineering measures in meeting the 2°C target, and, in particular, the even more ambitious 1.5°C target have increased noticeably over the past year, noting that carbon dioxide removal has already been extensively included in emissions scenarios. A heightened degree of attention is also reflected in the latest activities of the IPCC, where climate engineering has been addressed by all three Working Groups that contributed to the Fifth Assessment Report, and the forthcoming IPCC special report on the 1.5°C goal is equally expected to address the potential roles of both CDR and SRM technologies.

Against this background, the overarching objectives of CEC17 were:

1. Bringing together many of the debate's diverse stakeholders

2. Providing a forum to (1) present and discuss research results, (2) review the state of discussions around climate engineering, and (3) scope key research questions and challenges for academia and society

3. Providing a forum for experimentation with innovative session formats to address the complexity of issues around the topic of climate engineering

4. Providing a platform for networking, collaboration and exchange across disciplines, sectors (particularly academia, policy and civil society), countries, continents, and generations

Through this, CEC17 aimed to foster discussions around:

- The possible implications that the Paris Agreement might have for climate engineering research and development
- The potentials of climate engineering measures in helping to avoid or reduce some of the worst consequences of climate change
- The relationship between Solar Radiation Management (SRM), Carbon Dioxide Removal (CDR), mitigation and adaptation
- How an increasing differentiation between individual climate engineering proposals might affect the future of the "field" of climate engineering

- How research can be governed in a way that reduces the potential for unwanted side effects and at the same time enables research needed to provide a basis for informed decision-making

This report is a reflection on the conference proceedings and outcomes. It is not intended, however, to produce a definitive statement or set of recommendations. It rather serves to make many aspects of the discussions at the conference available to as broad an audience as possible. Thus, the report provides a concise, yet descriptive summary of the various plenary and parallel sessions that were held at CEC17. Where possible, the report includes hyperlinks to additional online resources such as video recordings from the plenaries and materials from individual sessions. All online resources linked to in this report can be accessed on the website www.ce-conference.org.

We also aim to make transparent the considerations that went into designing the conference concept, how we feel the conference concept shaped discussions at the conference and how we evaluate this, as well as the feedback we received and how we intend to incorporate it when designing the next CEC. At this point, we are also happy to announce that the positive feedback we received has reinforced our belief that CECs can provide an ongoing and important contribution to the critical global discussions about climate engineering, and we therefore intend to hold one or more future CECs in the coming years. We hope that many of you will join us for the next round of critical global discussions.

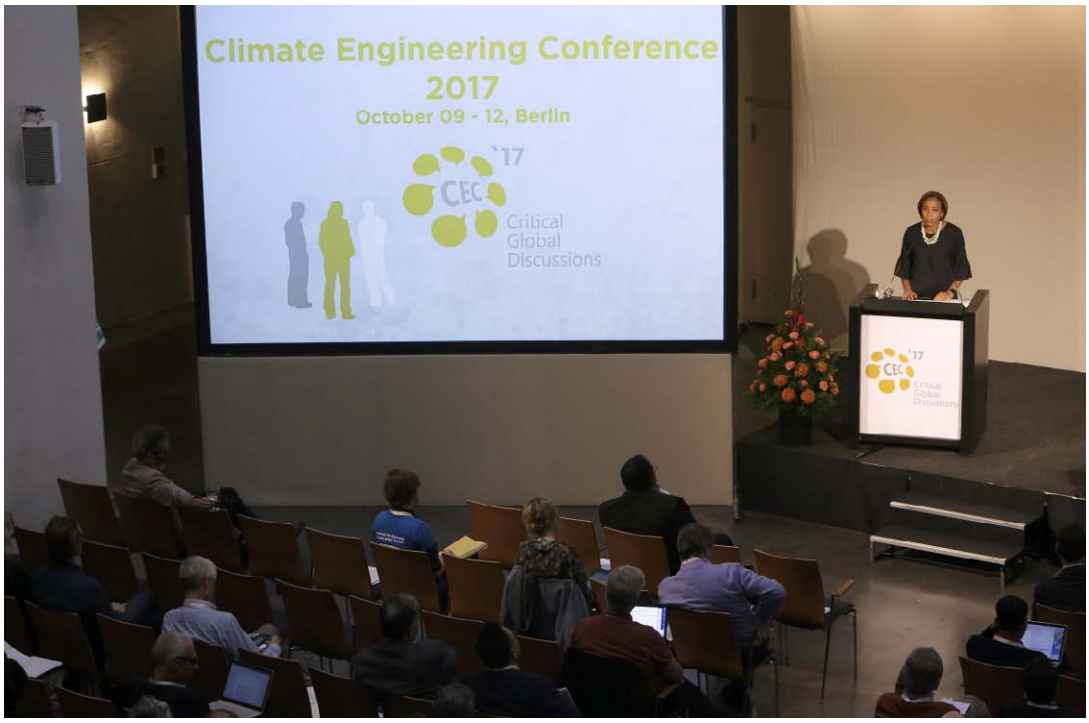
Mark G. Lawrence
Chair, CEC17 Advisory Group
Managing Scientific Director
Institute for Advanced Sustainability Studies

Stefan Schäfer
Chair, CEC17 Steering Committee
Project Leader, Climate Engineering
Institute for Advanced Sustainability Studies

1. CEC17 Plenaries

A total of five plenaries took place at CEC17 (see Annex III for an overview of the conference programme). The following subsections give an overview of these plenary events, including their composition and the main topics addressed in each discussion.

Opening plenary: Monday, October 9, 2017



Michelle Gyles-McDonnough, Executive Office of the Secretary General, United Nations (UN EOSG), giving her keynote speech at the CEC17 opening event
© IASS; Photo: Dirk Enters

Moderator:
Mark Lawrence – Institute for Advanced Sustainability Studies (IASS) Potsdam

Speakers:
Michael Taylor – University of the West Indies
Oliver Morton – The Economist
Michelle Gyles-McDonnough – Executive Office of the Secretary General, United Nations (UN EOSG)

This evening plenary session marked the official opening of the Climate Engineering Conference 2017. Mark Lawrence, Managing Scientific Director of the Institute for Advanced Sustainability Studies and Chair of the CEC17 Advisory Group, welcomed all conference participants on behalf of the IASS and introduced three keynote speakers, Michael Taylor of the University of the West Indies, author Oliver Morton and Michelle Gyles-McDonnough of the Executive Office of the Secretary General, United Nations (UN EOSG).

The full texts of the opening statements, along with the video of the plenary, can be accessed below.

↗ Welcoming address by Mark Lawrence (Advisory Group Chair) – Institute for Advanced Sustainability Studies (IASS) Potsdam

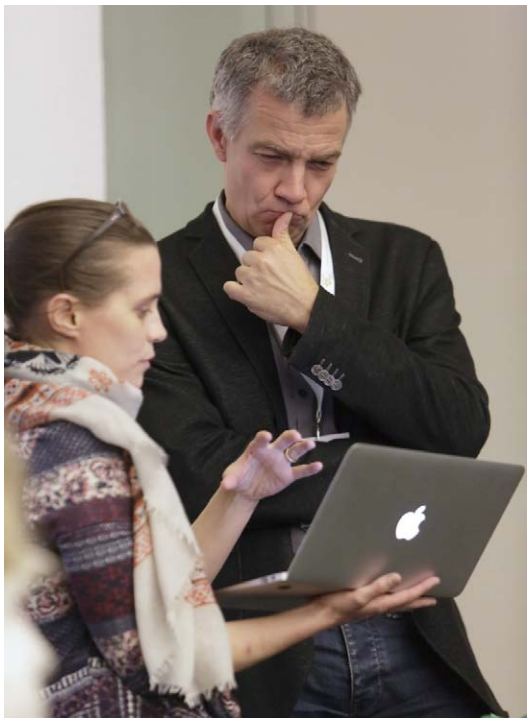
↗ **Keynote 1:** Climate Change and the Caribbean – The Take Away Messages: Speech by Prof. Michael Taylor, University of the West Indies

↗ **Keynote 2:** Re-imagining geoengineering and the world: Speech by Oliver Morton, The Economist

↗ **Keynote 3:** International Context for the Geoengineering Debate: Speech by Michelle Gyles-McDonnough, Director, Sustainable Development Unit, Executive Office of the Secretary-General, United Nations

↗ Opening Plenary Video

SRM & CDR updates + ignite-style talks on major projects



Naomi Vaughan – University of East Anglia and Andreas Oschlies – GEOMAR Kiel
© IASS; Photo: Dirk Enters

Linda Schneider – Heinrich Böll Foundation
© IASS; Photo: Dirk Enters

Moderator:
Stefan Schäfer – Institute for Advanced Sustainability Studies (IASS) Potsdam

Speakers:
Ben Kravitz – Pacific Northwest National Laboratory
Naomi Vaughan – University of East Anglia
David Keith – Harvard University
Douglas MacMartin – Cornell University, California Institute of Technology
Janos Pasztor – Carnegie Climate Geoengineering Governance Initiative (C2G2)
Linda Schneider – Heinrich Böll Foundation
Andreas Oschlies – GEOMAR Kiel
Phil Williamson – University of East Anglia & UK Greenhouse Gas Removal Research Programme
Andy Parker – Institute for Advanced Sustainability Studies (IASS) Potsdam & Solar Radiation Management Governance Initiative (SRMGI)

This plenary aimed to update all participants on the state of knowledge in natural and social science research on Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR), pointing interested listeners to individual sessions which would go on to cover the topics in more detail, and to introduce a set of key projects and initiatives in the field.

Stefan Schäfer, Chair of the CEC17 Steering Committee, opened the plenary with welcoming remarks, followed by overview talks on SRM and CDR given by Ben Kravitz and Naomi Vaughan, respectively, after which the following key projects and initiatives were introduced (see next page).

↗ **David Keith:** The Solar Geoengineering Research Program at Harvard University

↗ **Doug MacMartin:** The Gordon Research Conference on Radiation Management Climate Engineering: Technology, Modeling, Efficacy, and Risks

↗ **Janos Pasztor:** The Carnegie Climate Geoengineering Governance Initiative (C2G2)

↗ **Linda Schneider:** Heinrich Böll Foundation civil society engagement on climate engineering

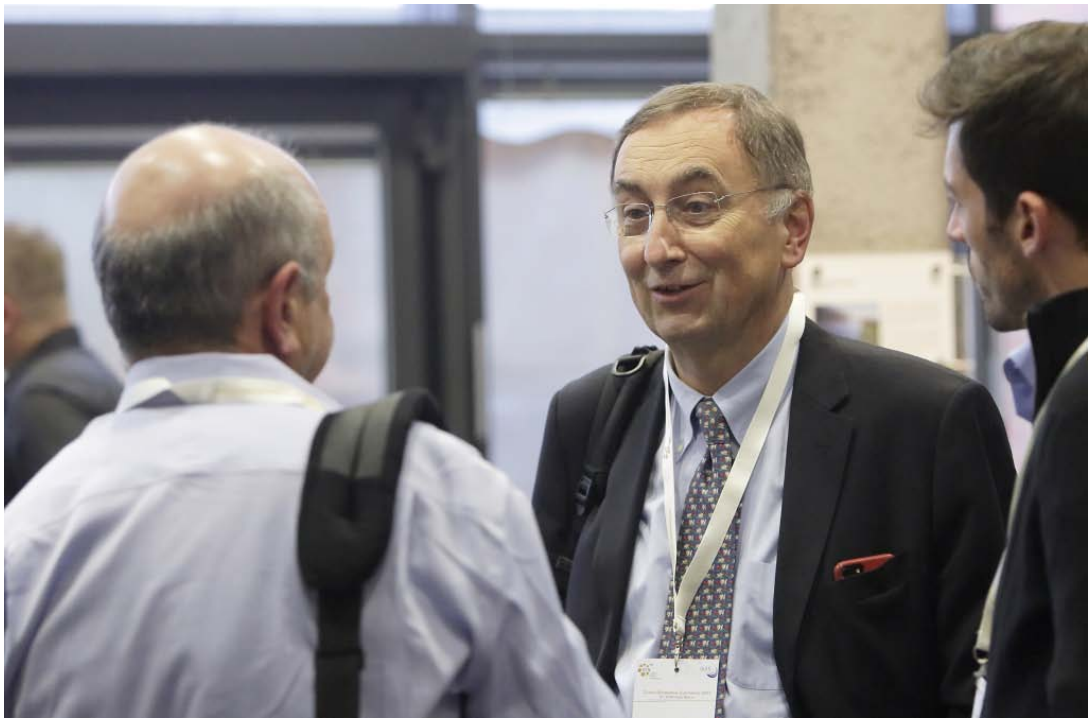
↗ **Andreas Oschlies:** German Research Foundation (DFG) Priority Programme (SPP) 1689: Evaulating the risks and side effects of Climate Engineering

↗ **Phil Williamson:** The UK Natural Environment Research Council (NERC) Research Programme on Greenhouse Gas Removal from the Atmosphere

↗ **Andy Parker:** Solar Radiation Management Governance Initiative (SRMGI)

Video of the plenary can be accessed below.

↗ Video of SRM and CDR update session



Janos Pasztor: The Carnegie Climate Geoengineering Governance Initiative (C2G2)

Panel discussion at the House of World Cultures: Climate Engineering in the Wake of Paris

Oliver Morton – The Economist

Moderator:
Oliver Morton – The Economist

Speakers:
Janos Pasztor – Carnegie Climate Geoengineering Governance Initiative (C2G2)
Pablo Suarez – Red Cross Red Crescent Climate Centre
Lili Fuhr – Heinrich Böll Foundation
Oliver Geden – German Institute for International and Security Affairs
H. Elizabeth Thompson – Sustainability consultant and former Assistant Secretary General of the United Nations
David Keith – Harvard University

The panellists at this public event discussed what the Paris Agreement can teach us about the potential for international cooperation on climate action and what role, if any, climate engineering might play in meeting the agreement's temperature targets. They also considered what the other, broader aims of climate policy must be, in terms of justice, precaution and democracy, and how climate engineering might fit with or stand in opposition to those aims.

Video of the plenary can be accessed below.

↗ Video of public panel discussion on Climate Engineering in the Wake of Paris

SRM Experiments Campfire

David Keith – Harvard University and Mark Lawrence – Institute for Advanced Sustainability Studies (IASS) Potsdam
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Moderator:
Mark Lawrence – Institute for Advanced Sustainability Studies (IASS) Potsdam

Speakers:
David Keith – Harvard University
Lizzie Burns – Harvard University
Frank Keutsch – Harvard University

A team of scientists at Harvard University is interested in conducting one of the first outdoor solar geoengineering experiments, possibly within a year or two. This session provided an opportunity for researchers to engage on the substance of the experiment and to discuss broader engagement. It also provided an opportunity for attendees to learn more about the planned experiment, ask the team questions, and offer input into a wide array of perspectives on the experiment, its scientific set-up, and the governance arrangements in place to guide it.

Climate Engineering Governance World Café

David Morrow – American University & Forum for Climate Engineering Assessment and
Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment

Moderator:
Edward (Ted) Parson – University of California, Los Angeles and Oliver Morton – The Economist

Facilitators:
Holly Jean Buck – University of California, Los Angeles
Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment
Peter C. Frumhoff – Union of Concerned Scientists (UCS)
Daniel Heyen – London School of Economics
Andrew Light – World Resources Institute and George Mason University
Duncan McLaren – Lancaster Environment Centre
Christine Merk – Kiel Institute for the World Economy
Pablo Suarez – Red Cross Red Crescent Climate Centre
Anjali Viswamohanan – Council on Energy, Environment and Water (CEEW)
Haomiao Du – University of Twente

This plenary aimed to stimulate creative exploration of climate engineering governance challenges and potential responses, by posing a few provocative questions in the form of brief challenge scenarios. The World Café format aimed to allow a more participatory and engaged discussion than normally possible in a plenary session. The plenary opened with a brief introduction of five challenge scenarios which were discussed at separate table groups. Participants chose which scenario they wished to discuss and joined a corresponding table group, each led by a designated "issue team leader" for a 30-minute discussion. Table representatives then re-convened to be debriefed for the plenary by Oliver Morton, who then facilitated a general plenary discussion.

The challenge scenarios discussed can be accessed below.

↗ Research Governance: Avoiding the Slippery Slope

↗ Good Enough Governance for Climate Engineering Proposals

↗ Interactions: CE Governance to Enhance (or at least Protect) Mitigation

↗ If the Cure is Worse than the Disease: Putting on the Brakes

↗ Catch-up Governance: Responding to a Deployment Challenge

Participants engaged in critical global discussions at the Climate Engineering Governance World Café

Town Hall: Looking forward

Andy Parker – Institute for Advanced Sustainability Studies (IASS) Potsdam and Solar Radiation Management Governance Initiative (SRMGI)

Moderators:
Andy Parker – Institute for Advanced Sustainability Studies (IASS) Potsdam and Solar Radiation Management Governance Initiative (SRMGI) and Oliver Morton – The Economist

Speaker:
Masahiro Sugiyama – University of Tokyo

This final plenary session served a dual purpose: it not only provided time to look back on the critical discussions conducted at CEC17 and to take stock of what had been learned, but it also gave participants the opportunity to look ahead and consider the roles that CDR and SRM might play in future climate policy. The session involved the presentation of preliminary results from a survey of the participants' opinions on future developments in the field of climate engineering. Subsequently, the participants were invited to respond to the results, deliberate, discuss, and share their own ideas about the future of the field.

Video of the plenary can be accessed below.

↗ Video of final Town Hall: Looking forward.

Participants engaged in critical global discussions at the Climate Engineering Governance World Café

2. CEC17 Sessions

Tuesday_10 October

Parallel Session 1.1: Communicating Climate Engineering

Covenor:
Holly Jean Buck – University of California, Los Angeles

Speakers:
Christine Merk – Kiel Institute for the World Economy
Geraldine Klaus – University of Kassel
Shinichiro Asayama – Waseda University
Aphiya Hathayatham – National Science Museum Thailand
Matthew Kearnes – University of New South Wales

The speakers discussed lessons learned from communicating about climate change and emerging technologies, and how those apply to communicating about climate engineering with different audiences. Christine Merk and Geraldine Klaus presented empirical results from studies about public perception/understanding of climate engineering. Shinichiro Asayama discussed what post-truth politics means for climate engineering debate. Aphiya Hathayatham talked about her experience communicating climate change to audiences in Thailand in her role as vice-president of the National Science Museum. Matthew Kearnes discussed how publics in his ethnographic research view soil carbon sequestration. Together, the presentations alluded to a diversity of audiences, but also many similarities. The role of live events and person-to-person communication versus new media channels were discussed.

Anjali Viswamohanan - Council on Energy, Environment and Water (CEEW), India
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Parallel Session 1.2: The Geoengineering Model Intercomparison Project: Where have we been and where should we go?

GeoMIP is one of the largest CE research projects in the world. This session aimed to discuss what it has done, what it is planning to do, and if it is meeting the needs of the broader CE research community. Alan Robock gave an overview talk on GeoMIP and some of the recent work he has been involved with on ecosystem velocities under climate change, geoengineering, and termination. Helene Muri talked about some results from the Norwegian EXPECT project in which they looked at comparisons of different methods of SRM and their resulting effects, primarily on the hydrological cycle. Simone Tilmes talked about a potential new geoengineering experiment for GeoMIP involving an overshoot simulation and meeting the 2°C target. Maxime Plazzotta talked about a new method of using volcanic eruptions as an emergent constraint on climate model results for stratospheric sulfate aerosol geoengineering, showing that for models that capture this constraint well, the climate system may be less sensitive to SRM. Masahiro Sugiyama talked about better incorporation of social science into GeoMIP, particularly for scenario design. The session sparked discussions about the current inability of climate models to adequately simulate cirrus cloud thinning, and the ways in which social science insights can be incorporated into comparative climate modelling work which will be taken up by the GeoMIP team.

Parallel Session 1.3: A change of course: Radical emission reduction pathways to stay under 1.5 ° C

Covenor:
Linda Schneider – Heinrich Böll Foundation

Speakers:
Lili Fuhr – Heinrich Böll Foundation & ETC Group
Barbara Unmüßig – Heinrich Böll Foundation
Karin Nansen – Friends of the Earth International
Silvia Ribeiro – ETC Group
Uwe Leprich – Umweltbundesamt
Bernd Nilles – Fastenopfer – Swiss Catholic Lenten Fund

This session was based on the premise that climate change is not an engineering problem and that there are many viable alternatives to bring global societies on a pathway towards 1.5°C without relying on climate engineering. This session explored how global societies could change course for a climate-just future. The session started with a short overview from Lili Fuhr on the need for radical emission reduction pathways, a critique of geoengineering and some thoughts on requirements for governing both SRM and CDR. Her input was followed by comments from Uwe Leprich and Silvia Ribeiro. After a round of questions and answers from the audience, the session continued with an input from Ann Kathrin Schneider on a way to stay under 1.5°C without geoengineering and a comment by Bernd Nilles on technology critique from a Catholic perspective. Discussions during the session demonstrated that academics and civil society representatives sometimes find it difficult to understand each other due to the different terminologies and narratives used in the academic and climate justice civil society communities.

Parallel Session 1.4: Achieving the SDGs: Governing Geoengineering in a post-Paris world

Covenors:
Janos Pasztor – Carnegie Climate Geoengineering Governance Initiative (C2G2), Kai-Uwe Schmidt – Carnegie Climate Geoengineering Governance Initiative (C2G2), Nicholas Harrison – Carnegie Climate Geoengineering Governance Initiative (C2G2)

Speakers:
Wenjiang Zhang – World Meteorological Organisation (WMO)
Michelle Gyles-McDonnough – Executive Office of the Secretary General United Nations (UN EOSG),
David Cooper – Secretariat of the Convention on Biological Diversity (SCBD)
Youba Sokona – The South Centre

Governance of climate geoengineering is a very challenging endeavour on many levels and may become a necessity given the level of demonstrated ambition to act. In a World Café setting, participants were invited to hear what UN officials, policymakers, researchers and civil society organisations have to say about why geoengineering governance must be discussed in the context of urgent, accelerated mitigation efforts and delivery of the Sustainable Development Goals (SDGs). Discussions were stimulated by short presentations provided by leading voices from the international climate change and SDG policy community. The discussions highlighted that: different governance approaches may be needed for different types of climate engineering research; there is a need for the development of flexible or adaptive climate engineering governance; and that aligning governance between counties is a central challenge, where the UN has a key role to play.

Parallel Session 1.5: The economics of climate engineering: The recent past and the road ahead

Covenors:
Daniel Heyen – London School of Economics,
Juan Moreno-Cruz – Georgia Tech School of Economics

Speakers:
Tobias Pfrommer – University of Heidelberg
Vassiliki Manoussi – Athens University of Economics and Business (AUEB) & Fondazione Eni Enrico Mattei (FEEM)
Gernot Wagner – Harvard University
Jessica Strefler – Potsdam Institute for Climate Impact Research (PIK)

This session was based on the premise that economic methods are crucial for both normative and descriptive assessments of Climate Engineering (both SRM and CDR). The session gave an overview of the current state of economic knowledge and offered room for discussing where the field should move from here. The presentation "A Liability Model For Regional Solar Radiation Management Impacts" by Tobias Pfrommer discussed different liability schemes of SRM, in particular in the context of free driver externalities where agents disagree in terms of the optimal SRM level. The presentation "Climate Engineering under Deep Uncertainty" by Vassiliki Manoussi highlighted that different levels of caution might be the reason why different agents may have different preferences over SRM deployment. She focused on the role of SRM in a model with the feature of deep uncertainty simulated as model misspecification of SRM side effects. The presentation "An Economic Anatomy of Optimal Climate Policy" by Gernot Wagner introduced geoengineering into an optimal control model of climate change economics, discuss-

ing the interdependency of mitigation, adaptation, CDR and SRM. Finally, Jessica Strefler's presentation focused on CDR, emphasizing how mitigation can alleviate the trade-offs between high transitional challenges and high CDR deployment. The discussions highlighted that the economic analysis of CE can provide valuable insights to other disciplines, and that close links ought to be maintained with related disciplines like scientific modelling and political sciences as economic modelling of different climate engineering approaches continues.

Slides from some of the individual speakers' presentations can be accessed below.

↗ **Tobias Pfrommer:** A Liability Model For Regional Solar Radiation Management Impacts

↗ **Vassiliki Manoussi:** Climate Engineering under Deep Uncertainty

Gernot Wagner: An Economic Anatomy of Optimal Climate Policy

Parallel Session 1.6: SRMGI 1: SRM research across Asia

Covenor:
Shinichiro Asayama – Waseda University

Speakers:
Ying Chen – Chinese Academy of Social Sciences
Saroj Mishra – IIT Delhi
Lie Wu – Beijing Normal University
Yuan Xin – Development and Research Center of China Meteorological Administration

To date most Solar Radiation Management (SRM) research has taken place in Europe and America but this is beginning to change quite quickly. This session showcased social and physical science research across Asia, featuring speakers from India, China and Japan. SRMGI governance workshops have taken place in India and China and a workshop on SRM and the role of Asia-Pacific was held in Tokyo in spring 2016. The presentations showed some common traits of SRM research in Asia. For instance, the natural scientific research, especially climate modelling research, is at the center of their research programs, in some coordination with governance debates. Second, in modelling research there is perhaps a greater focus on the impacts of SRM deployment in Asian regions rather than its global effectiveness. Third, regarding the possibility whether field experiment of SRM might be conducted in Asia or not, there was somewhat subtle agreement among the speakers that to date scientists and policymakers in these three countries have not shown any signs of moving into field experimentation, thus it is perhaps unlikely to take place in Asia in the near future. But at the same time, there is a shared recognition that SRM research – on both modelling and governance – will continue to grow across Asia, thus there is need for capacity-building among local scientists and increased public debate of the issues surrounding SRM.

Parallel Session 1.7: God(s) and Greenhouse Gases: Religion and Climate Engineering

Covenors:
Forrest Clingerman – Ohio Northern University, Laura Hartman – University of Wisconsin–Oshkosh, Thomas Bruhn – Institute for Advanced Sustainability Studies (IASS) Potsdam

Speakers:
Mark Lawrence – Institute for Advanced Sustainability Studies (IASS) Potsdam
Fletcher Harper – GreenFaith
Cynthia Scharf – Carnegie Climate Geoengineering Governance Initiative (C2G2)

This session aimed to discuss what insights religions can have on new technologies, asking specifically what religions may have to say about climate engineering, and whether they may help us ask important questions about this topic. The session aimed to highlight that these insights can go beyond questions of "playing God" to questions of harmony, agency, and justice.

One of the clearest conclusions that emerged from this session was a consensus that the study of religion has an important role in discussions on climate engineering. For some participants, the importance of this topic was based on personal spiritual or religious commitments: in effect, many within the climate engineering community are reflecting on how their own worldview informs their moral and political understandings of climate engineering. Even for people who do not have strong religious or spiritual commitments, religion has an impact on social discussions of climate change and climate engineering. Fletcher Harper suggested in his comments at the session that religion offers us tools for moral emotion. Further discussion raised the point that religion also informs moral reflection beyond emotion. Religious communities, in fact, have historically been locations for such debates. Similarly, religious communities are pivotal for advancing vocabularies and frameworks for justice. Throughout the discussion of the session, the need for continued engagement between religion and climate engineering was reiterated. Participants seemed eager for continuing discussion on spiritual values and climate engineering.

Parallel Session 1.8: Public Engagement & Climate Engineering: Whither and How?

Covenors:
Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment, Michael Thompson – Forum for Climate Engineering Assessment

Speakers:
Arunabha Ghosh – Council on Energy, Environment and Water
Jane C.S. Long – Retired, formerly Lawrence Livermore National Laboratory
Rob Bellamy – Institute for Science, Innovation and Society (InSIS), University of Oxford
Masahiro Sugiyama – University of Tokyo
Peter C. Frumhoff – Union of Concerned Scientists (UCS)
Holly Jean Buck – University of California, Los Angeles

It is widely acknowledged that engaging a wider range of people in conversations about climate engineering is desirable. Rather than reporting out specific insights derived from existing public engagement work, this panel aimed to step back and address issues related to the rationales, promises, and challenges associated with public engagements in this domain more generally. While public engagement is not in and of itself a panacea, it can lead to improved outcomes. The panel presented a variety of views on how best to do public engagement, but there was broad agreement that: 1) There is a need for public engagement efforts to involve more listening, rather than talking; 2) engaging people in thinking about climate engineering in early education could be a more effective in aiding better thinking about the topic; and 3) the social license to operate is important and therefore a key goal of public engagement, in addition to improved outcome. The speakers agreed that challenges remain, including particularly lack of public familiarity with the topic of climate engineering and

frame effects. It was pointed out that further work is needed to understand which stakeholders should be engaged, to delineate responsibilities of researchers and funders of researchers in this space to ensure that field research proposals are subject to legitimate societal review and scrutiny, and to design public engagement that is appropriate for non-Western societies. The speakers identified several key next steps, including mapping stakeholders, institutionalizing public engagement and improving scientist's abilities to act with meaningful transparency in their research.

Parallel Session 1.9: To Gabon or not to Gabon: A game on geoengineering research and policy

Covenor:
Pablo Suarez – Red Cross Red Crescent Climate Centre

During this intensely interactive session, participants used a playable system dynamics model of the changing relationships between information, decisions and consequences to explore the individual and collective options for managing climate risks. There were winners and losers, and prizes. Most importantly, there was serious fun in the context of rich, realistic discussions about current and future climate policy choices. During the game, participants were given information about a weather event and asked to decide what kinds and level of disaster avoidance to implement. Dice were used to determine whether a disaster had taken place. Action that was not needed was costly, but not as much as refraining from action when a disaster took place. The odds were changed progressively to reflect changing climate.

The ultimate point was when each group was given one of the dice, which were made of foam, and told that they could choose to cut away a small piece to change the odds of the game. Some intense deliberation took place about whether the dice should be cut. One group decided yes, the other decided no. The game convenor then decided that he was unilaterally going to cut one of the dice, with an electric carving knife. He asked members of the group what they would do to stop him. After an attempt to unplug the carving knife failed, the game was then ended. The game elicited some highly charged emotional responses. During the subsequent discussion, it was pointed out that the two participants whose physical interventions led to the game being ended were women (who were a minority in the session as a whole) and the question was raised as how this may relate to women's protests to protect the environment.

Parallel Session 1.10: Security Risk Pathways of Climate Engineering and Counter-Geoengineering: Conflict or Cooperation?

Convenors and Speakers:
Jürgen Scheffran – Universität Hamburg, Daniel Heyen – London School of Economics, Joshua Horton – Harvard University, Jasmin S. A. Link – University of Hamburg, P. Michael Link – University of Hamburg

The session discussed whether climate engineering may lead to security risks and conflicts or whether it will rather promote cooperation and governance. As an example, the speakers discussed in detail whether counter-geoengineering (the release of neutralizing particles or of potent greenhouse gases) would pose an additional risk or could help overcome the free-driver problem. During the session, it was widely acknowledged that climate engineering and counter-geoengineering raise many interesting aspects in the context of international relations, strategic interaction and security issues. The very lively debate revolved around the plausibility of unilateral climate modification and counter-geoengineering as well as cooperation possibilities and incentives. The main disagreement that emerged in this session is whether it is plausible that single actors deploy climate engineering unilaterally and whether counter-geoengineering will be seen as a feasible option. Moreover, there was disagreement regarding countries' willingness to cooperate over technological interventions in the climate system. The fishbowl group discussion format worked very well, as it allowed the convenors to bring in different perspectives while keeping the discussion lively and structured.

Parallel Session 1.11: Policy options and principles for negative emissions and SRM

Covenor:
Matthias Honegger – Institute for Advanced Sustainability Studies (IASS) Potsdam & Perspectives Climate Change

Speakers:
Albert C. Lin – University of California, Davis School of Law
Axel Michaelowa – Perspectives Climate Change & University of Zurich
Jesse Reynolds – Utrecht University
Gernot Wagner – Harvard University
Andrew Light – World Resources Institute and George Mason University
Stephan Singer – Climate Action Network International

This session aimed at discussing a number of specific policy proposals to address questions of governance of negative emissions and solar radiation management, noting in particular the need to orient governance discussions on climate engineering around existing frameworks and decision-making processes, as well as base such discussions on established principles of international law. The session was set up as a classical panel session with five input presentations, followed by responses that put the presentations in a broader context and raised critical questions regarding the operationalization of the proposed policy approaches.

There was general agreement among the speakers that both negative emissions as well as Solar Radiation Management posed important questions for international governance – in the near-term as well as in the context of long-term policy planning. Furthermore, there was an agreement that governance approaches could potentially be derived from existing

frameworks, principles, provisions and decision-making processes. While a number of specific approaches were discussed, there seemed to be an implicit agreement that it was worth further exploring these alongside other novel approaches and that it was too early to select or exclude particular approaches. It was noted that decisions over the design of policies would ultimately be political decisions and thus up to multilateral negotiation processes and the governments represented therein to eventually take up particular governance proposals over time. Yet it was also stated very clearly that in emerging policy fields there was an important role for researchers and research institutions as well as environmental and social non-governmental organizations to develop and advance governance suggestions and to engage proactively in conversations with government representatives in the spirit of democratic processes.

Slides from the individual speakers' presentations, can be accessed below.

↗ **Matthias Honegger** – Paris market mechanisms for negative emissions and the role of the SDGs

↗ **Albert C. Lin** – CDR After Paris: The Need to Incentivise Without Committing

↗ **Axel Michaelowa** – Cost–effective mitigation including negative emissions – the role of markets and MRV

↗ **Jesse Reynolds** – Human rights and climate engineering policy

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Parallel Session 1.12: Key Elements of Responsible Geoengineering Research

Covenors:
Jane C.S. Long – Retired, formerly Lawrence Livermore National Laboratory, Steven Hamburg – Environmental Defense Fund (EDF)

Speakers:
Janos Pasztor – Carnegie Climate Geoengineering Governance Initiative (C2G2)
Edward (Ted) Parson – University of California, Los Angeles
Douglas MacMartin – Cornell University, California Institute of Technology
Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment

Given that plausible IPCC scenarios require intentional climate intervention to stay below 1.5/2°C, and geoengineering research may commence soon, this session discussed the call for responsible research to simultaneously develop governance capacity. The session was focused on identifying what such responsible research will require: Activities to allow legitimate decision making, enabling reliable research, and control over experimentation.

Wednesday_11 October

Parallel Session 2.1: Trumped! A new politics of climate engineering?

Covenors:
Duncan McLaren – Lancaster Environment Centre, Olaf Corry – Copenhagen University

Speakers:
Eduardo Viola – University of Brasilia
Holly Jean Buck – University of California, Los Angeles
Simon Nicholson – American University & Forum for Climate Engineering Assessment
Oliver Geden – German Institute for International and Security Affairs
Shinichiro Asayama – Waseda University
Nnimmo Bassey – Health of Mother Earth Foundation (HOMEF)

This session explored implications for national and international politics of climate engineering of the Trump administration's brand of climate denialism and other turns towards populism and authoritarianism. Some of the questions discussed included: How do views on, or reactions to climate engineering vary with political tendencies such as nationalism/populism? What does media ownership (concentration of ownership) mean for the distribution of opinions likely to dominate the discussion? Given the weakening of the multilateral institutions under nationalist/isolationist tendencies, how might prospects for long-term SRM-governance be affected? What does a possible normalization/revolt against authoritarianism imply for climate engineering – a push-back scenario? The session identified many reasons for concern about the populist and authoritarian turn in politics, but also revealed important uncertainties about how these might play out. More broadly it highlighted the resurgence of politics, in contrast with a post-political administrative rationality, in global affairs, and opened up valuable and animated discussion about such issues. In turn these revealed some of the limitations of rational deliberation over governance mechanisms for research or deployment of climate engineering.

Parallel Session 2.2: Climate engineering: What goes up must come down

Covenors:
Tim Butler – Institute for Advanced Sustainability Studies (IASS) & Freie Universität Berlin, Simone Tilmes – National Center for Atmospheric Research, Sebastian Eastham – Harvard University

Speakers:
Lauren Marshall – University of Leeds
David Keith – Harvard University
Lili Xia – Rutgers University
Alan Robock – Rutgers University

Based on the premise that what goes up must come down, this session's discussons focused on the question: If particles are pumped into the stratosphere, how will that affect air quality at the ground level? The session highlighted many of the uncertainties regarding the impacts of possible climate engineering technologies on air quality, including the potential effect of stratospheric sulfate aerosol injection on surface ozone concentrations and intensity of surface UVB radiation; the rate and pattern of sulphur deposition following injection of sulphur into the stratosphere; and localized air quality impacts of direct air capture. Overall, the session was broad in scope, covering disparate sources of concern with respect to links between climate engineering and air qual-

ity. However, this accurately represented the lack of maturity with regards to research into these impacts. Above all, the principal aim – to stimulate discussion on the topic of air quality in the context of climate engineering – was achieved. The session also highlighted the need for research into as yet unconsidered air quality impacts of some climate engineering technologies. Most significantly, it was acknowledged that technologies already included in economic forecasts, namely bio-energy with carbon capture and storage (BECCS), have not been evaluated in terms of air quality impacts.

Parallel Session 2.3: Climate engineering governance beyond international law

Covenors:
Jesse Reynolds – Utrecht University
Tracy Hester – University of Houston

Speakers:
Anthony Chavez – Northern Kentucky University
Jeffrey McGee – University of Tasmania
Edward (Ted) Parson – University of California, Los Angeles
Rachel Hauser – University Corporation for Atmospheric Research (UCAR)

Most legal scholarship concerning climate engineering has remained within the international domain. Yet national and non-state law and policy will likely be relevant sooner. This session presented and discussed possible next steps in these regulatory domains toward governance of both solar and carbon climate engineering. The panel concluded that national and regional governance requirements are much more likely to govern climate engineering activities within a nation's jurisdiction rather than broader international governance regimes still in development. While existing laws and mandates can likely be readily extended to certain types of climate engineering (such as Australian ocean protection laws that could apply to ocean iron fertilization and RPS options for NETs), the longer-term role for national and regional governance will need to include new emerging laws and codes of conduct that offer more flexible and adaptable pathways (such as social license governance approaches). The speakers agreed that, given the likely prominence of national and regional governance for emerging climate engineering technologies, future research will need to clarify exactly how existing national requirements must be modified to best oversee climate engineering research and activities. By the same token, additional research on social license approaches and codes of conduct will sharpen needed non-legal local strategies to complement legal mandates under national and regional laws.

Parallel Session 2.4: Who needs the Anthropocene?

Covenor:
Oliver Morton – The Economist

Speaker:
Mark Lawrence (Advisory Group Chair) – Institute for Advanced Sustainability Studies (IASS) Potsdam

This session was focused on the question: Is the Anthropocene a useful concept in discussions of climate engineering – or of anything else? The idea that human interactions with the planet are the defining feature of our age is widespread, and widely seen as problematic. The panellists discussed the usefulness of the idea of the Anthropocene and audience members were also strongly encouraged to contribute to the discussion.

Parallel Session 2.5: Interdisciplinary CDR

Covenor:
Naomi Vaughan – University of East Anglia

Speakers:
Nils Markusson – University of Lancaster
Lena Boysen – Max Planck Institute for Meteorology
Rob Bellamy – Institute for Science, Innovation and Society (InSIS), University of Oxford
Elmar Kriegler – Potsdam Institute for Climate Impact Research (PIK)
Vivian Scott – University of Edinburgh

Methods to remove carbon dioxide from the atmosphere impact on a range of physical and human systems and are intertwined with mitigation and adaptation approaches through land use, food systems, energy policy and water quality. There are a number of trade-offs, implications, risks and opportunities for different CDR methods and approaches that may influence the feasibility of large scale deployment of such techniques. Crucial bottlenecks or co-benefits of particular combinations of CDR, mitigation and adaptation strategies may play a crucial role in realising large scale CDR implementation and are thus important to identify. This session, which included 5 presentations from a wide diversity of disciplines (public perceptions of governance, biogeochemical modelling, integrated assessment modelling, EU policy frameworks, and cultural political economy of mitigation deterrence), aimed to discuss a variety of forms of CDR and a range of disciplinary perspectives. The discussions highlighted that there is a lot of work to be done to scrutinise different CDR approaches from a range of perspectives, given the large scale use of CDR assumed in future emission scenarios.

Thursday_12 October

Parallel Session 3.1: SRMGI 2: How to involve the climate community and the scientific community in debating climate engineering in developing countries?

Covenor:
Eduardo Viola – University of Brasilia

Speakers:
Aphiya Hathayatham – National Science Museum, Thailand
Paulo Artaxo – University of São Paulo
Ratemo Waya Michieka – University of Nairobi
Penehuro Lefale – LeA International/Massey University

Climate engineering is almost unknown in the general scientific communities in developing countries and totally unknown to the general public. Consequently, the importance of understanding the scientific and socio-political issues raised by Solar Radiation Management (SRM) is underestimated in the Global South. The significant expansion of interest about SRM in many developed countries in recent years has not been matched in developing countries. This is a major obstacle to having a broad, inclusive and equitable international discussion. Developing countries are generally the most affected by climate change and would be most affected by the use or rejection of SRM. They, therefore, have a major stake in the international governance of SRM and should be centrally involved in potential decisions about deployment. This panel discussed the causes of the problem and aimed to think through the best way to increase CE awareness in developing countries. The goal of this discussion is not to promote constituencies in favour or against SRM, but to increase awareness about the need for knowledge about the fundamental questions involved following the international debate. The main points discussed included the fact that, although SRM is not a priority for developing countries, scientist from developing countries should follow the research on SRM and should participate in debates about the international governance of research. There was agreement that some scientists from developing countries should participate on research groups on SRM, and that the new DECIMALS fund being established by SRMGI is a very promising initiative. In addition, some participants emphasised that it was very important to advance modelling on potential regional and local impacts of SRM.

Parallel Session 3.2: Geoengineering and the Arctic

Covenors:
Ben Kravitz – Pacific Northwest National Laboratory, Douglas MacMartin – Cornell University, California Institute of Technology

Speakers:
Ulrike Lohmann – ETH Zurich
David Mitchell – Desert Research Institute
Holly Jean Buck – University of California, Los Angeles
Rafe Pomerance – Arctic 21
Hilairy Hartnett – Arizona State University
Helene Muri – University of Oslo
Ilona Mettiäinen – Arctic Centre, University of Lapland

The Arctic is experiencing some of the most rapid climate change anywhere in the world. Offsetting these changes has been the explicit target of multiple geoengineering proposals. The potential effects of climate change and climate engineering would impact the people and natural resources of this sensitive region and would have knock-on effects for numerous areas throughout the rest of the world. This session aimed to explore the broad scope of geoengineering and the Arctic. Discussion topics ranged from CDR & SRM technologies that are designed to be deployed in or directly impact the Arctic, natural and social science research on the effects and impacts of geoengineering on the Arctic, and the geopolitical role of the Arctic. The wide range of presentations helped to highlight some of the key issues in an area that arguably needs vastly increased attention. An interesting tension emerged between the reported interests of Arctic peoples and the interests of industry and researchers in the audience who had some experience with the Arctic. Some participants were interested in how the different perspectives might be reconciled to produce a coherent strategy for talking about SRM and its effects on the Arctic. There were also some vigorous discussions on the effectiveness of cirrus cloud thinning, and just how well we understand ice physics and whether we know enough to manipulate those physics in ways that are useful. The session made it clear that cirrus cloud thinning is still a huge uncertainty. In addition, a key take away message was that the Arctic might serve as an interesting focal point for competing interests in the future, and preparing for that conversation could prove useful.

Parallel Session 3.3: Two pathways for Sulphate Aerosol Injection: Towards conditions of ethically defensible research and deployment

Covenors:
Konrad Ott – Christian–Albrechts–Universität zu Kiel, Christian Baatz – Christian–Albrechts–Universität zu Kiel

Speakers:
David Morrow – George Mason University
Frederike Neuber – Karlsruhe Institute of Technology (KIT)

Based on two stylised Sulphate Aerosol Injection (SAI) deployment scenarios ("emergency" and "peak shaving"), this session aimed to investigate under which conditions SAI research and deployment can be ethically defensible (permissible or mandatory). The session also considered what this implies for present policy making and research programs. Although there was no unified outcome of the session, there was agreement on some points: First, that trust is a very complicated notion and that it is at least not straightforward to justify prohibitions of deployment (not to mention research) based on this notion. Second, that the arguments presented need to be developed in more detail. Third, that the Peak Shaving/Buying Time scenario is ethically preferable to the

Emergency deployment scenario, and that this has implications for regulating deployment. There were also several points of contention during the discussions: First, to what extent research on SAI is needed at present (i.e. to what extent it is ethically desirable) and to what extent it, too, should be regulated; Second, whether trust and intentions really do matter; Third; whether the Trump administration and other collective agents that ignore mitigation related duties should be allowed to research SAI; Fourth, to what extent SAI may create both winners and losers; Fifth, whether "relative SAI losers" have reasons to complain if they are among those most vulnerable to climate change; and sixth, whether reduced mitigation because of SAI means that one cannot plausibly refer to Peak Shaving/Buying Time SAI deployment anymore. The discussions at the session will inform ongoing exploration of the relationship between mitigation related duties and the ethical permissibility of SAI research programs and deployment plans. These findings will then be combined with feasibility considerations and a discussion about which (un) desirable consequences may follow from attempts to enforce prohibitions of deployment/research.

Parallel Session 3.4: CE assessment metrics – Comparative, Integrative, Comprehensive

Covenors:
Nadine Mengis – Concordia University, Sebastian Sonntag – Max Planck Institute for Meteorology, Elnaz Roshan – Universität Hamburg, International Max Planck Research School on Earth System Modeling, Andreas Oschlies – GEOMAR Kiel, Wilfried Rickels – Institut für Weltwirtschaft Kiel, Hermann Held – Universität Hamburg

Speakers:
Peter Irvine – Harvard School of Engineering and Applied Sciences
Yann Chavaillaz – Ouranos Inc and Concordia University
Mohammad Khabbazan – Universität Hamburg
Nils Matzner – Alpen–Adria–Universität Klagenfurt

Based on the premise that, to enable fair, comprehensive and comparative decision-making on Climate Engineering (CE), a multidisciplinary and integrative selection process for assessment metrics is needed, this session aimed to foster discussions about approaches to comparatively assess different Climate Engineering ideas, both among each other and in the context of mitigation. Questions discussed included: Which indicators/time scales/regions should be used for a thorough assessment of CE? Is a top-down or a bottom-up approach preferable for the assessment of CE? Which are the indicators to use for the integrated assessment? Is it sufficient to use the indicators proposed by the IPCC ARII? While the purpose of the session was not to find an answer to the question on which indicators to select, it was meant to raise the awareness on the challenge for an appropriate CE assessment. One finding was that the assessment in general needs to be broadened in the sense that more disciplines need to enter the field. Apart from that a concern was raised that an appropriate CE assessment also needs to comprise the termination of a given measure to fully account for all the future impacts. The discussion highlighted that, for future research on CE, there is a need to reflect more on what indicators are used and which ones are currently being disregarded by the research community, thereby identifying research gaps in the ad-hoc CE assessment process. It might also be necessary to reformulate integrated assessment models to make them more specific for the task of CE assessment.

Parallel Session 3.5: The Earth System and Carbon Dioxide Removal

Covenors:
David P. Keller – GEOMAR Helmholtz Centre for Ocean Research Kiel, Andrew Lenton – CSIRO Oceans and Atmosphere & Antarctic Climate and Ecosystems Cooperative Research Centre, Vivian Scott – University of Edinburgh, Naomi Vaughan – University of East Anglia

Speakers:
Helene Muri – University of Oslo
Sebastian Sonntag – Max Planck Institute for Meteorology
Jiajun Wu – GEOMAR Helmholtz Centre for Ocean Research Kiel
Miriam Ferrer González – Max Planck Institute for Meteorology

Scenarios limiting warming to <2°C rely heavily on Carbon Dioxide Removal (CDR). Despite this, many key questions around potential efficacy, impacts and feedbacks of different proposed CDR methods remain unanswered. This session explored the response of the Earth System, i.e. the climate system, biosphere, and the carbon cycle, to proposed CDR. The first presentation showed that in an idealized case CDR might be able to reverse climate change, at a global scale, but perhaps not at the local scale. Helene Muri, showed how BECCS would have limited potential and perhaps even be detrimental in some cases. Miriam Ferrer showed how there is a large CDR potential for ocean alkalinization, but that it requires massive and perhaps unfeasible amounts of alkaline minerals. Sebastian Sonntag compared a few CDR and SRM methods to show that the potential of afforestation is limited, while ocean alkalinization and SRM may have more potential to prevent climate change. Jiajun Wu introduced a new CDR method where carbon is sequestered in the ocean by growing macroalgae on floats and sinking it into the deep ocean. Overall, the presentations showed that, while some methods may have a high CDR potential, while appear to be quite limited. Additionally, for all methods, understanding is quite limited and most studies have been quite idealized. Carbon cycle and climate feedbacks, which influence the atmospheric CO_2 reduction efficacy of the methods, are just starting to be explored, and combinations of different CDR methods have also not yet been looked at. Therefore, less idealized simulations need to be conducted, and combinations of CDR methods need to be investigated.

Parallel Session 3.6: A Review of the Recommendations of the Academic Working Group on International Governance of Climate Engineering

Covenors:
Simon Nicholson – American University & Forum for Climate Engineering Assessment, Michael Thompson – Forum for Climate Engineering Assessment, David Morrow – American University & Forum for Climate Engineering Assessment, Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment

Speakers:
Aarti Gupta – Wageningen University
Andrew Light – World Resources Institute and George Mason University
Leslie Paul Thiele – University of Florida, UF CAIRES
Prakash Kashwan – University of Connecticut

The Academic Working Group (AWG) on International Governance of Climate Engineering has been meeting across a series of workshops to take a fresh, authoritative look at international governance pathways for solar geoengineering. This was the first public discussion of their preliminary findings and recommendations. Members of the AWG presented their draft report, followed by commentary from report reviewers.

Parallel Session 3.7: Modelling, imagining, and making the future in climate engineering

Covenors:
Sean Low – Institute for Advanced Sustainability Studies (IASS) Potsdam, Stefan Schäfer – Institute for Advanced Sustainability Studies (IASS) Potsdam

Speakers:
Ben Kravitz – Pacific Northwest National Laboratory
Holly Jean Buck – University of California, Los Angeles
Andrew Jones – Climate Interactive & Massachusetts Institute of Technology
Silke Beck – Helmholtz Centre for Environmental Research (UFZ)
Peter Healey – University of Oxford

This session was based on the premise that research into the impacts of climate change, as well as of strategies to reduce them, is anticipatory: decisions in the present have to be taken on the basis of projected futures. Gauging the physical and societal implications of deploying SRM or CDR at planetary scales currently relies on a host of speculative research methods, from modelling (earth systems and impacts models, economic and game theoretical models, integrated assessment models) to more qualitative approaches such as surveys, scenarios, analogies, and simulative gaming. These methods are used to explore future trends, contingencies, and actor dynamics to inform current research and policy agendas. Some, like models, aim more at a degree of prediction and forecasting by simulating geophysical and societal dynamics; others are more experimental and aim at providing a platform for communication between different stakeholders and bodies of disciplinary knowledge. But each method comes with different objectives, 'ways of knowing' the future, communities of usage, and

access to decision-making processes. This session aimed to discuss the questions: How is knowledge and decision-making – on potentially game-changing technologies that don't exist – better served? Are we predicting the future, exploring possibilities, presenting alternatives, or setting our own conceptions of the future into play? Communication was fostered between the communities that practice future oriented methods, and discussions focused on their perceived benefits and flaws, resonance in the debate to date, and value going forward. The idea that projected or imagined futures – as research activities contextualized by a highly charged political debate – contain implicit or instrumental claims upon the proposed shape of current actions was explored. As researchers responsible for assessing SRM or CDR through speculative methods, the participants discussed how the boundaries of debate are shaped by the processes or results of their research, and questioned what is, or should be, the role of research – and researchers – in policy-relevant and politically charged contexts. Much focus was placed on the emergence of BECCS in integrated assessment models work, as the single most iconic example of resonant future-claiming in the climate engineering space, though much room remains for the interrogation of climate models, social science methods (including foresight), and broader methods of imagining and projecting. The discussions highlighted that further interdisciplinary conversations are needed between scholars and practitioners in the range of economic, climate modelling, social science, risk assessment, and futuring toolboxes on their value – separately and as a whole – for deriving knowledge in climate engineering. There is a need to bring to the fore the awareness of "future-making": in assessing the future, scholars are themselves bringing possibilities into play that shape decision making, that demand further avenues of research, and that implicate the development of certain technologies.

Parallel Session 3.8: Climate Engineering Research Starting and Stopping Rules

Covenors:
Clare Heyward – University of Warwick & Institute for Advanced Sustainability Studies (IASS) Potsdam, David Keith – Harvard University

Speakers:
Anjali Viswamohanan – Council on Energy, Environment and Water (CEEW)
Rodel Lasco – World Agroforestry Centre (ICRAF)
Nadine Mengis – Concordia University

This campfire session aimed to elucidate participants' views on "stopping rules" – the conditions under which people might consider downscaling or ceasing research into CE technologies, and "starting rules" – conditions under which people may advocate a dramatic increase in research, or the commencement of research at the next level of scale (e.g. a move to outdoor experiments). Some participants were invited to present some initial thoughts in order to kick-start a group discussion. All participants were invited to reflect on others' views and refine their own in the course of the discussion. One participant said that at this stage, all that was needed were standard health and safety rules. Another participant argued that one appropriate stopping rule would be if countries conducting climate engineering research failed to meet their mitigation commitments. Other participants argued that this would be very difficult to enforce and that if countries did not meet their mitigation commitments, that was actually when research would be needed. Overall, there was more disagreement than agreement among the participants, and discussion of broader concerns dominated. One of these was whether a robust system of stopping rules could be implemented and if so, what that meant for how climate engineering research should proceed. Another concern raised was whether proposed process experiments were facing undue "regulatory burdens". One key area of discussion was the definition of thresholds above which an experiment or programme needs to be appropriately subject to additional oversight. It was remarked that such thresholds often seemed arbitrary and did not always seem to alleviate concerns, as there was frequently a justification to cross the next "un-crossable" line. The point was raised that perhaps the idea of conceptualising starting and stopping "rules" is too difficult or even inappropriate. It was agreed that more discussion of these issues was necessary in a variety of formats.

Parallel Session 3.9: Putting the 'Engineering' in Solar & Carbon Climate Engineering Approaches

Covenors:
Ben Kravitz – Pacific Northwest National Laboratory, Douglas MacMartin – Cornell University, California Institute of Technology

Speakers:
David Keith – Harvard University
Simone Tilmes – National Center for Atmospheric Research
Wake Smith – New State Capital Partners LLC
Hugh Hunt – Cambridge University

Modifying Earth's climate is one of the largest proposed activities in history. Designing, constructing, and managing such a large endeavour would require engineering. This session aimed to explore engineering questions from both a systems and deployment perspective and how they can inform the science of SRM and CDR climate engineering. The participants discussed a range of topics including: new work involving incorporation of control theory into climate model simulations as a way of meeting chosen climate objectives in the presence of irreducible uncertainty; the potential for aircraft design for SRM deployment; general concerns related to engineering in SRM, including trade-offs in uncertainties, and timescales of various approaches; and lessons learned from the SPICE project, with a focus on the importance of personnel and safety concerns in doing field tests. One point of agreement during the discussions was that there is no sense in researching or governing something that is impossible to deploy from an engineering perspective, and therefore the climate engineering research community should be engaging with engineers more actively.

Discussions at an NGO led session on radical emission reduction pathways to stay under 1.5°C.
© IASS; Photo: Dirk Enters

Parallel Session 3.10: Campfire Sessions on a Code of Conduct for Geoengineering Research

Covenor:
Anna–Maria Hubert – University of Calgary

Speakers:
Miranda Boettcher – Institute for Advanced Sustainability Studies (IASS) Potsdam
Jane Flegal – UC Berkeley & Forum for Climate Engineering Assessment
Tim Kruger – Oxford Geoengineering Programme (OGP), University of Oxford & Origen Power
Janos Pasztor – Carnegie Climate Geoengineering Governance Initiative (C2G2)

Based on the premise that it is essential that geoengineering research be appropriately governed to ensure that any such research is conducted safely and in a socially responsible and equitable manner, this session described initial work by the Geoengineering Research Governance Project (GRGP) on developing a draft Code of Conduct for geoengineering research and actively invited comment and discussion about potential next steps. The project aims were described as being:

↗ To further examine the regulation and governance of research and innovation on geoengineering and its progressive development, drawing upon the insights of different disciplinary perspectives

Presentation of World Cafe group discussions
© IASS; Photo: Dirk Enters

↗ To apply the results of this research to improving the text of the draft Code of Conduct with the aim of informing the design of appropriate regulatory and governance frameworks for research and innovation on geoengineering

↗ To disseminate and use this research to engage with researchers, policy experts, commercial entities, and civil society representatives to understand the regulatory and governance options, and to integrate this feedback by revising the previous version of the draft Code of Conduct

A revised version of the draft Code was presented and discussed at the session (see link below). Two major points of discussion raised included: the dual nature of governance as a way to both enable safe and useful climate engineering research, and to provide oversight of such research, and possible pathways to the adoption and implementation of the Code.

The revised Code of Conduct can be accessed below:

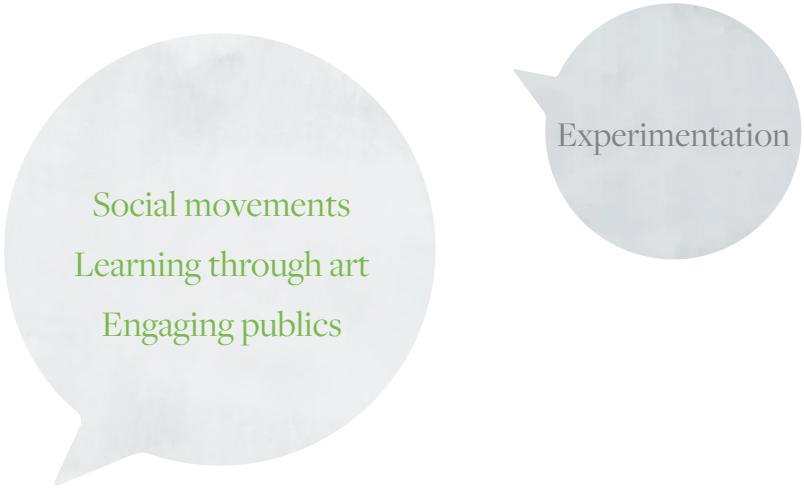
↗ Code of Conduct for Responsible Geoengineering Research, October 2017

Parallel Session 3.11: Performative Experiments in Geoengineering

Covenors:
Karolina Sobecka – Interdisciplinary artist,
Dehlia Hannah – Aarhus University

Speakers:
Holly Jean Buck – University of California, Los Angeles
Oliver Morton – The Economist
Forrest Clingerman – Ohio Northern University
Christopher Coenen – Karlsruhe Institute of Technology (KIT)

When artists perform experiments they elicit very different responses from the public than when scientists do. With this in mind, this session aimed to open up a space for transdisciplinary conversation by engaging conference participants in the performance and observation of a small scale artistic experiment that maps choreographies and protocols of the climate engineering field: a staging of a performance and observation of an experiment depicted in the painting 'Experiment on a bird in the air pump'.



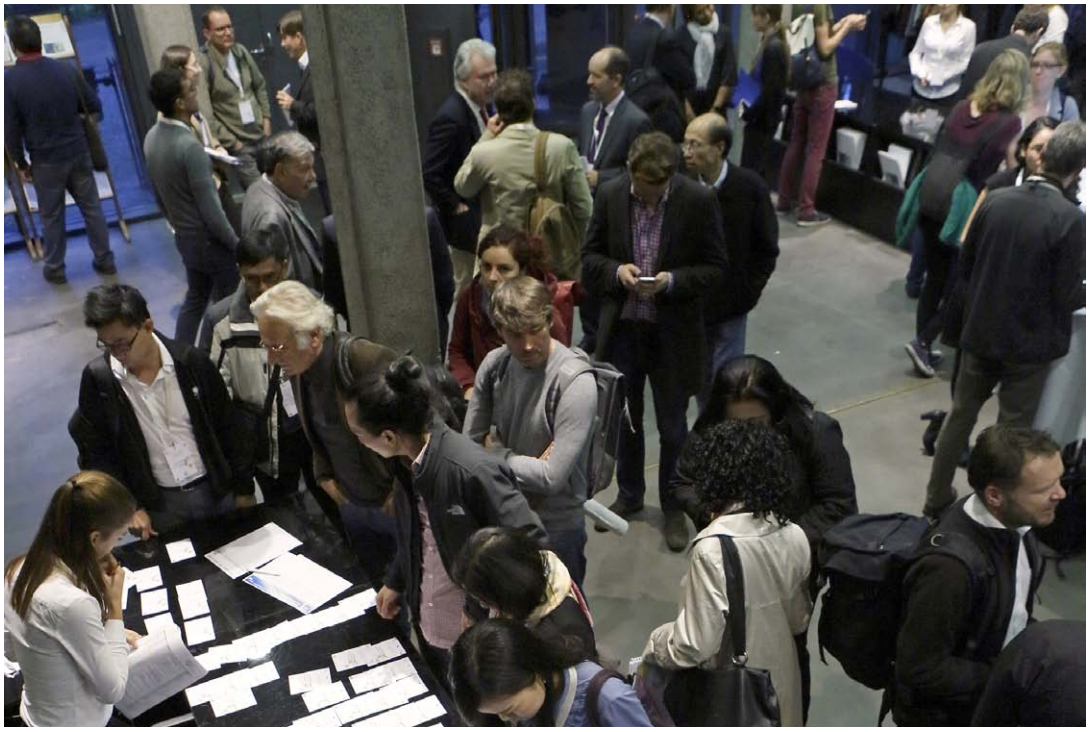
Parallel Session 3.12: Social Movements & Climate Engineering Justice from the Periphery

Covenors:
Patrick Taylor-Smith – National University Singapore
Jim Thomas – ETC Group
Duncan McLaren – Lancaster Environment Centre

Speakers:
David Morrow – American University & Forum for Climate Engineering Assessment
Aniruddh Mohan – Wuppertal Institute for Climate, Environment and Energy
Octavio Rosas – Landa – National University Mexico
Nnimmo Bassey – Health of Mother Earth Foundation (HOMEF)

Debate around the justice of geoengineering has often, implicitly or explicitly, assumed the perspective of high-emitting groups that are disproportionately responsible for geoengineering research. This session was based around the idea that the field re-orient its normative thinking regarding climate engineering research, governance, and deployment to include the agency and perspectives of the global South and subaltern groups. The session convened global representatives from diverse social movements to lead intersectional discussions on what geoengineering means for racial and environmental justice, food sovereignty, youth, gender, health and global justice as well as climate justice. One of the key findings of the panel was that the difference between even relatively applied-oriented academics and activists on these issues is still fairly wide. These individuals did not share the same concerns, theories of social change, or vocabularies. Yet, all agreed that existing practices—in research, policy, and governance—need to take more seriously the concerns found in the developing world. Also, everyone agreed that it was unfortunate that so few scientists, who are really driving the research agenda, attended the panel. It was pointed out that more work needs to be done to understand the precise environmental risks that the developing world will face in the event of different kinds of climate engineering. Furthermore, this research needs to be done with an eye towards the fact that the values and interests of those in the developing world may not be the same as current researchers. It was additionally highlighted that, while structural critiques of both society and science itself are important, those who engage in those critiques need to expend more effort on how to operationalize those criticisms into recommendations that are useful to people doing research or policy work.

CEC17 group photograph in the plenary hall
© IASS; Photo: Dirk Enters



Participant registration
© IASS; Photo: Dirk Enters

3. Participant feedback

Did CEC17 meet its overall objectives? In this section we draw upon responses to a feedback form completed by conference participants as well as the insights of the organisers to reflect upon this question. On the whole, reviews from conference participants were positive. However, it is important to note that, while feedback was positive in general, individual conference participants' views as expressed in the conference feedback forms, and subsequently in communications with the organisers, differed on some of the aspects discussed below.

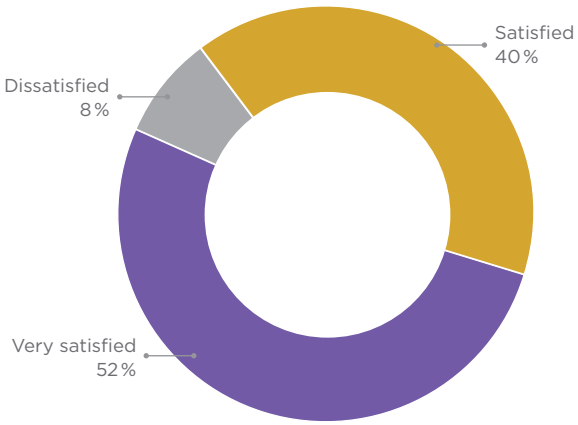
Overall satisfaction

The majority of conference participants who took part in the feedback survey indicated they were very satisfied (52%) or satisfied (40%) with CEC17 overall. Based on this feedback, the conference organisers feel that there is continued support for future transdisciplinary conferences of this type on the range of issues related to climate engineering technologies.

Objective1: *Bringing together many of the debate's diverse stakeholders*

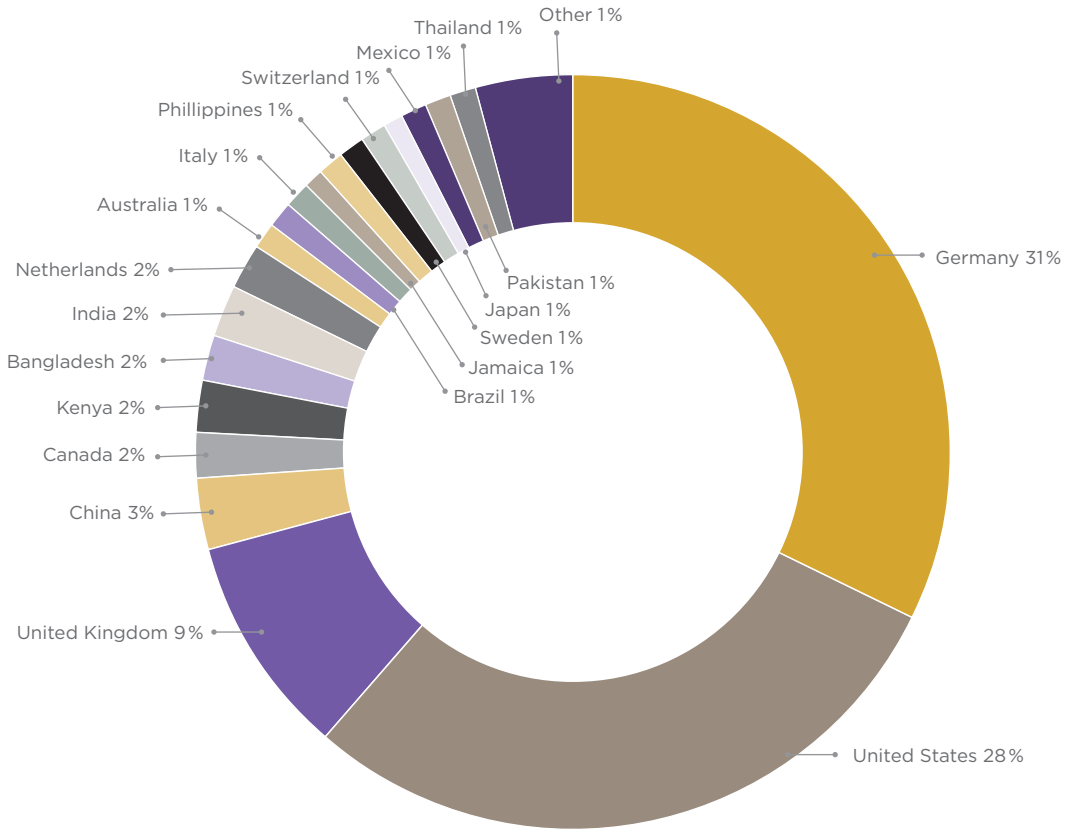
CEC17 aimed to bring together as many of the debate's diverse stakeholders as possible to facilitate interaction between participants from a range of different disciplines, geographic and cultural backgrounds and political perspectives. 260 participants from more than 30 countries attended the conference, including approximately 50 representatives from the Global South, thanks largely to the collaboration with the Solar Radiation Management Governance Initiative (SRMGI). In addition, a significant number of representatives from non-governmental and civil society organisations were in attendance, along with some delegates from national and intergovernmental policy circles. In general, feedback indicated that the majority of attendees were satisfied with the level of participant diversity. Such diverse participation contributed to the comprehensiveness of topics covered, something that was once again highlighted by many

Figure 1: How did you like CEC17?



participants as a strength of the conference. However, there were several aspects which participants indicated could be improved. These included: Encouraging attendance by more policy representatives from a wider range of national and intergovernmental levels; providing developing country participants with the opportunity to take on more central roles at the conference; improving the gender balance among session speakers; actively encouraging attendance and participation by more natural scientists and engineers; and reducing the prominence of the more well-established academics in the programme to provide early-career researchers with more opportunities to present and discuss their work.

Figure 2: CEC17 Participants' nationalities



Objective 2: *Providing a forum to (1) present and discuss research results, (2) review the state of discussions around climate engineering, and (3) scope key research questions and challenges for academia and society*

In response to feedback following CEC14, the conference organisers again allowed a large degree of freedom for conference participants to shape the conference content via open solicitation of session proposals. This process was designed to provide academics with the opportunity to present and discuss their research results and to allow civil society and academics alike to gain a thorough and timely update on the latest developments in the field. The sessions were complemented by the conscious design of plenaries that addressed a wide variety of key

topics to bring the diverse CEC17 participant group together to discuss broader questions and challenges related to climate engineering. Given that a majority of conference participants (74%) indicated the topics discussed at the conference covered their fields of interest, another 24% said their interests were partially covered, and only 2% of respondents indicated that they were not given the opportunity to discuss topics that interested them at the conference, this approach to designing a balanced conference programme can be considered successful.

However, some participants raised the point that a disproportionately large number of the sessions were focused on social science, law or politics (72%), while only a smaller number of sessions were dedicated to natural science, economics and engineering topics (28%). This may indicate the need for a balancing of topical coverage by the Steering Committee to achieve a balanced conference programme for future events of this kind.

Figure 3: Did the topics cover your field of interest?

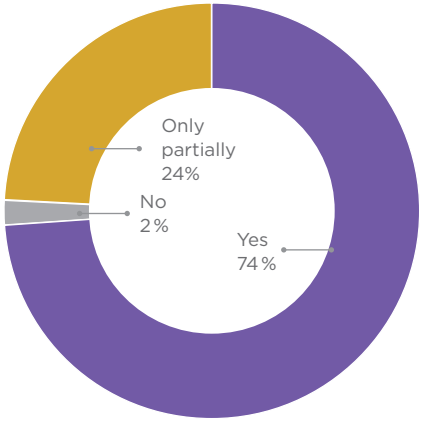
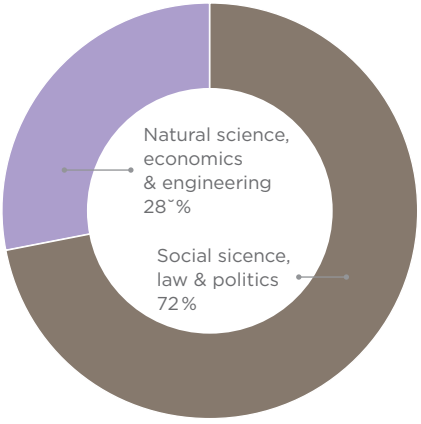


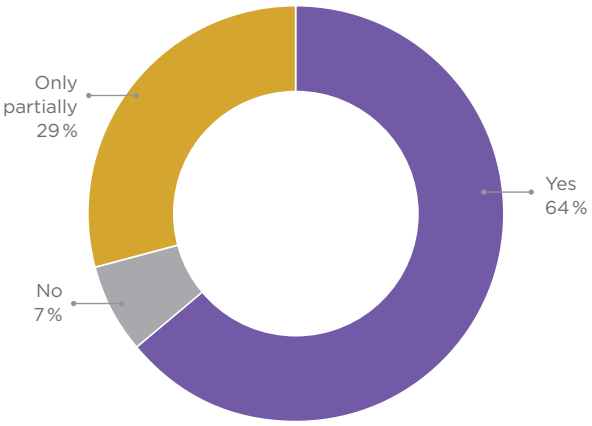
Figure 4: Session topics



Objective 3: *Providing a forum for experimentation with innovative session formats to address the complexity of issues around the topic of climate engineering*

When the first CEC was held in 2014, despite efforts being made to encourage non-traditional session formats, most of the sessions convened by participants used a traditional conference format: a series of presentations by experts, followed by short discussion or question and answer periods. While this format clearly has a place at an academic conference, the organisers received particularly positive feedback on the few less traditional sessions that involved a lot of audience interaction. Therefore, during the CEC17 planning process, the organisational team retained more influence over the format of sessions. The organisational team, with the help of the Steering Committee and Advisory Group, compiled a list of suggested session formats (including the traditional presentation format, but offering six others as well), which session convenors were asked to select from when planning their sessions (see Annex 4). This resulted in a larger variety of session formats at this years' conference than was the case in 2014. During the conference, the organisers received substantial positive feedback on the success of the more interactive session formats. This is reflected in the results of the feedback survey, which indicate that the 64% of participants completely agreed, and a further 29% partially agreed that the formats were supportive of dialogue and participation. The fact that 7% still felt that some formats were not conducive to participation could reflect the decisions by some session convenors to adhere to more standard academic session formats, or may also indicate that there is room for improvement in the selection of interactive session formats going forward.

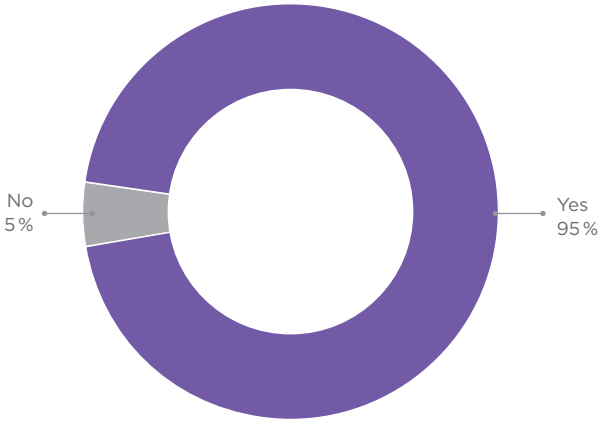
Figure 5: Were the formats supportve of dialogue/partcipaton?



Objective 4: *Providing a platform for networking, collaboration and exchange across disciplines, sectors (particularly academia, policy and civil society), countries, continents, and generations*

The conference organisers aimed to integrate adequate opportunities and incentives for interaction and networking into the conference programme. As is the case with most conferences, many of the participants who responded to the survey found that the breaks and social events were the most conducive to making new connections. However, the more interactive sessions and plenaries were also mentioned as useful opportunities to network and engage with those from a different community of knowledge or practice. Overall, a large majority of survey respondents (95%) indicated that they were completely satisfied with the opportunities to make new connections at the conference.

Figure 6: Were you satisfied with the opportunites to make new connections?



4. Looking forward

As was the case with CEC14, the conference organisers encouraged discussions during and after CEC17 to gauge opinions on the value of a continued series of large-scale conferences as an appropriate forum for critical global discussions of climate engineering. This section will discuss several questions that were raised with regard to the future of the CEC.

Is there value in continuing to have a "climate engineering conference" series which includes a wide range of both carbon dioxide removal and solar radiation management approaches?

In the last three years, it has increasingly been questioned whether climate engineering should be considered a singular topic at all. Some argue that the individual proposals subsumed under the umbrella term are too heterogeneous to be usefully referred to under a collective heading, and that the individual geoengineering proposals and their specific portfolios of costs, benefits, and risks should be considered and discussed separately in order to assess whether they can and should become part of a policy portfolio for addressing climate change. This has led to a debate as to whether it makes sense to continue to host a comprehensive "climate engineering conference" which includes all proposed approaches summarised under the umbrella term. In the lead up to the conference, the CEC17 Steering Committee proposed that the question as to the appropriateness of continuing to discuss both sets of technologies under the umbrella term climate engineering, and, accordingly, whether convening a conference on "climate engineering" makes sense in the future, should be integrated throughout the conference.

Discussions regarding the merits of "lumping vs. splitting" the topics were carried out at several sessions during the conference without a clear consensus being reached. However, it became clear that, while the differentiation of climate engineering approaches had progressed significantly since 2014, there were still benefits to be had from continuing to discuss both carbon and solar climate engineering approaches at future CECs. One major reason raised for continuing to discuss both sets of approaches together is the blurry line between some of the approaches. Some participants emphasised that solar radiation management approaches could be expected to have some carbon dioxide removal effects – for example by increasing the carbon update and retention properties of soils at cooler temperatures – and vice versa. It was argued that separating discussions of the two sets of approaches may limit discussions to separate expert communities and reduce the opportunity for integrated learning about interrelated earth-system dynamics. In addition, it was stated that the inclusive CEC format facilitates consideration of the broader context in which scientific and technological development take place, and encourages discussion of the social, political and ethical questions that arise when considering planetary processes as an object of intervention independent of the method used for this. Therefore, the CEC organisational team would like to see future CECs continue as open forums for discussion of the range of technologies contained within the umbrella of climate engineering, and the broader issues that come into view when discussing this highly complex and interlinked topic.

How can future CECs balance the need for focused disciplinary discussions with the desire for broader transdisciplinary interactions?

CEC17 once again intended to provide a venue for explorations of climate engineering via disciplinary research, interdisciplinary collaboration, and transdisciplinary engagement. In disciplinary research, specific questions are addressed from a single disciplinary perspective at a great level of specialization and depth. In interdisciplinary collaboration, specific questions are addressed simultaneously from different disciplinary perspectives. In transdisciplinary engagement, new approaches that merge more traditional disciplinary perspectives with input from different stakeholder communities, such as academics, NGOs, the media, and policymakers, provide new frameworks for discussing issues of collective interest and relevance.

It became apparent during the conference and follow up discussions that it was quite difficult to balance the need for these varying types of interactions in the overall conference programme. Some participants reported that there was a tension between the desire for high-level disciplinary discussion and transdisciplinary interaction at CEC17. While well-established academics were looking for forums in which to conduct high-level discussions of their disciplinary research, early-career researchers were seeking opportunities to present and discuss their emerging ideas, and policy and civil society representatives were interested in broad, inclusive debates about the range of issues related to the proposed technologies.

The conference organisers recognised the need to establish ways to balance these differing expectations at future CECs. Suggestions for how this could be done include: More effectively communicating the unique role of the CEC series to manage the expectations of participants; organising a more interactive poster session to allow early-career researchers to present and invite discussion on their work; and labelling sessions to make a clear distinction between disciplinary and transdisciplinary formats to ensure those who want to go to a strictly disciplinary session to have in-depth topical discussions can choose to do so, while those more interested in broader discussions can attend sessions with a transdisciplinary focus. As an important step, the CEC conference organisers have already started and will continue to work more actively with the organisers of the primarily disciplinary Gordon Research Conference series to strengthen the complementary nature of both the series.

How can greater inclusivity be ensured at future CECs?

CEC17 aimed to bring together as many of the debate's diverse stakeholders as possible to facilitate interaction between participants from a range of different disciplines, geographic and cultural backgrounds and political perspectives. While this was largely achieved, the geographical, sectoral and gender diversity of participants could be further improved upon at future CECs (see section 3). In particular, feedback indicated that the CEC17 partnership with the Solar Radiation Management Governance Initiative (SRMGI) to enable larger numbers of developing country participants to attend the conference should be continued for future conferences. In addition, the organisational team was encouraged to actively seek out new partnerships with other organisations to facilitate the participation of more policy, intergovernmental and NGO representatives. Another potential improvement to be taken into consideration for future CECs, which was mentioned by several participants during and after the conference, is increasing the size of the conference venue to allow for the acceptance of more applicants, and preferably relocating the event to a conference hotel to increase opportunities for more social and interpersonal interaction between participants.

Annex I: Conference Steering Committee and Advisory Group

The **Steering Committee** is an interdisciplinary group of twelve early-career researchers responsible for making final decisions on the intellectual content and format of the conference.

Stefan Schäfer (Steering Committee Chair)
Stefan Schäfer leads the research group "Climate Engineering in Science, Society and Politics" at the Institute for Advanced Sustainability Studies in Potsdam, Germany. His research examines the politics, philosophy and history of science and technology, with a particular focus on the emerging field of climate engineering. He was a guest researcher at the Berlin Social Science Center (WZB) from 2009–2012 and a fellow of the Robert Bosch Foundation's Global Governance Futures program in 2014–2015. He is a contributing author to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, lead author of the European Transdisciplinary Assessment of Climate Engineering (EuTRACE) report, and chairs the Steering Committee of the Climate Engineering Conference (CEC) series. He holds a doctorate in political science from Freie Universität Berlin.

Miranda Boettcher
Miranda Boettcher is a research associate at the Institute for Advanced Sustainability Studies in Potsdam, Germany. Her research interests include climate engineering governance and the interplay of language, knowledge and power in political decision-making processes. She has previously worked as a research analyst for Foresight Intelligence in Berlin, Germany, an investigator at the Mintz Group in San Francisco, USA, and a research assistant at the University of Heidelberg's Depeartment of International Relations in Heidelberg, Germany.

Holly Jean Buck
Holly Jean Buck is a NatureNet Science Fellow at UCLA's Institute of the Environment and Sustainability. Her research interests include agroecology and climate-smart agriculture, energy landscapes, land use change, new media, and science and technology studies. At present, she is studying the socio-political feasibility of using solar geoengineering to scale up carbon removal. She has written on several aspects of climate engineering, including humanitarian and development approaches to geoengineering, gender considerations, and the social implications of scaling up negative emissions. She holds a doctorate in Development Sociology from Cornell University and a MSc in Human Ecology from Lund University, Sweden. She lives in Los Angeles, California.

George Collins

George Collins has worked on a variety of climate change topics, including common-law climate litigation, international treaty processes, a Bayesian framework for climate negotiations, and the embedding of agent-based political models inside global climate models. Within climate engineering, his current research interests include potential humanitarian consequences, interactive methods for exploring complexities and uncertainties, and communications heuristics for minimizing the possibility that high-leverage climate engineering might interfere with efforts to effectively mitigate greenhouse gas emissions. He works with several nonprofit organizations on gaming and scenario planning in the context of climate change, and is a co-founder of the Geoengineering Scenarios Working Group. By day, he works at a law firm in San Francisco that represents corporate whistleblowers. George received his J.D. from the Yale Law School along with a Masters in Environmental Management from the Yale School of Forestry and Environmental Studies.

Daniel Heyen

Daniel Heyen is a postdoctoral researcher in environmental economics. He is based at the Grantham Research Institute at the London School of Economics. His research focuses mainly on the role of uncertainty and learning in environmental decision-making and the intergenerational and strategic challenges raised by climate engineering technologies. Daniel holds a PhD in Economics from Heidelberg University.

Clare Heyward

Clare Heyward is Project Scientist at the Institute Advanced Sustainability Studies. Previously she was a Leverhulme Early Career Fellow at the University of Warwick, working on the project Global Justice and Geoengineering. Clare is interested in issues of global distributive justice and intergenerational justice, especially those connected to climate change. Before joining the University of Warwick, she was James Martin Research Fellow on the Oxford Geoengineering Programme, where she researched ethics and governance issues raised by the prospect of using geoengineering technologies as a response to climate change.

Ben Kravitz

Ben Kravitz is a climate scientist in the Atmospheric Sciences and Global Change Division at the U.S. Department of Energy's Pacific Northwest National Laboratory. His research involves using climate models to understand climate response to perturbations on a variety of timescales. Ben's focus is on climate model simulations of geoengineering. He is the coordinator of the Geoengineering Model Intercomparison Project (GeoMIP), an international effort to understand the robust responses of climate models to standardized scenarios of geoengineering.

Sean Low

Sean Low is a research associate at the Institute for Advanced Sustainability Studies in Potsdam, Germany. His research focuses on the uses and limits of scenario and gaming methods, as part of anticipatory frameworks for the governance of emerging technologies, to explore how solar geoengineering approaches can be assessed and regulated. Sean has previously done research on the politics of climate engineering and global climate politics at the Centre for International Governance Innovation and the University of Waterloo (Canada).

Steering Committee

Nigel Moore

Nigel Moore is Manager of Global Programs and Initiatives at the Waterloo Institute for Sustainable Energy, located at the University of Waterloo in Canada. He currently manages an international consortium of institutions working to address energy poverty with renewable energy solutions. Previously he spent five years in the field of climate engineering at the Institute for Advanced Sustainability Studies (Germany), the Oxford Geoengineering Programme (UK) and the Centre for International Governance Innovation (Canada). The focus of his work on climate engineering is the governance of research, particularly the application of the principle of transparency through mechanisms of research disclosure. In his previous capacities he has created an online library of reference material on CE and has been involved in the organization of conferences, summer schools, workshops, and public seminars aimed at increasing the availability of reliable information about CE to interested publics and providing venues for deepened discussions amongst experts.

Andy Parker

Andy Parker is the project director for the SRM Governance Initiative (SRMGI). Formerly he was a research fellow at the Institute for Advanced Sustainability Studies. He has a background in climate policy and has worked on solar geoengineering for over nine years, including as a research fellow at the Harvard Kennedy School and a senior policy adviser at the Royal Society. He was a member of the UN Convention on Biological Diversity's expert working group on geoengineering.

Scott Vivian

A researcher at the University of Edinburgh, Vivian Scott works on carbon capture and storage (CCS), energy and climate policy, and assessing the potential and consequences of 'negative emissions' technologies and approaches to support mitigation. His research focuses on technical and policy development to support deep decarbonisation of the economy, the potential for CCS principals and technologies to be applied to manage carbon in the climate system; understanding the development of climate and energy policy and the interaction between technical and political perspectives; and understanding the role and implications of large amounts of CO_2 or carbon removal and storage on the climate system. He is co-leader of the Carbon Dioxide Removal Model Inter-comparison project (CDR-MIP). More generally, he is interested in the interactions between society, the carbon cycle and climate system, and the intergenerational responsibilities and feedbacks these generate.

Naomi (Nem) Vaughan

Naomi (Nem) Vaughan is a lecturer at the Tyndall Centre for Climate Change Research in the School of Environmental Sciences at the University of East Anglia. Her research interests focus on possible societal response options to climate change; mitigation, adaptation, carbon removal or 'negative emissions' and ideas of climate engineering. Her focus is on these issues at a global scale and over a long time (e.g. centuries), how they are constrained by the Earth system (including climate-carbon cycle feed-backs) and how they interact with one another. Nem is an interdisciplinary scientist working from a physical science background with colleagues across a range of disciplines.

The Advisory Group consists of a diverse set of eminent researchers and practitioners in the science, policy, and civil society communities, who are engaged in discussions relevant to climate engineering. The Advisory Group provide recommendations to the Steering Committee.

Mark Lawrence (Advisory Group Chair)

Prof. Dr. Mark Lawrence is Managing Scientific Director at the Institute for Advanced Sustainability Studies (IASS). His primary areas of research are the impacts and mitigation of short-lived, climate-forcing pollutants (SLCPs), and on the potential impacts, uncertainties and risks of climate engineering. He received his Ph.D. in 1996 in Earth and Atmospheric Science from the Georgia Institute of Technology in Atlanta, (USA). His Ph.D. research was mainly conducted at the Max-Planck-Institute for Chemistry (MPIC) in Mainz. From 2000 until 2005, he led an independent junior research group at the MPIC, and in 2006 he took over the atmospheric modelling group at the MPIC. He received his Habilitation in 2006 at the University of Mainz, where he also served as interim professor for meteorology during 2009–2010, winning the 2010 annual Teaching Award from the State of Rheinland-Pfalz, as well as a University Teaching Award. In 2011 he moved to the IASS, and in 2014 he was appointed as an Honorary Professor at the University of Potsdam. Prof. Lawrence is author or co-author of over 100 peer-reviewed publications. He co-coordinated the EU project "MEGAPOLI" (2008–2011) and coordinated the project "EuTRACE" (European Transdisciplinary Assessment of Climate Engineering, 2012–2014). He has served as editor for the journals Atmospheric Chemistry and Physics, and Atmospheric Environment, and has served or serves on various international committees, most notably the Scientific Steering Committee of the International Global Atmospheric Chemistry project (IGAC, for which he is co-chair from 2015–2018), the Science Team of the UNEP Atmospheric Brown Clouds project (ABC), and the international Commission on Atmospheric Chemistry and Global Pollution (iCACGP), as well as being a contributing author of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

Ken Caldeira

Ken Caldeira is an atmospheric scientist in the Department of Global Ecology at the Carnegie Institution at Stanford University. He also serves as a professor in Stanford's Department of Environmental Earth System Science. Caldeira's research focuses on the long-term evolution of the climate and global carbon cycle; marine biogeochemistry and chemical oceanography, including ocean acidification; and energy technologies and geoengineering. Previously, Caldeira was with the Energy and Environment Directorate at the Lawrence Livermore National Laboratory. He received his B.A. from Rutgers College and both his M.S. (1988) and Ph.D. (1991) in atmospheric sciences from New York University. In 2000, he was a co-author of the first study to use a climate model to investigate solar climate engineering. In 2009, he served on the UK Royal Society panel that produced a report on geoengineering, and on the panel that produced the reports on climate engineering for the US National Academy of Sciences.

Arunabha Ghosh

Paulo Artaxo is Professor of Environmental Physics at the University of São Paulo (Brazil). He is a member of the IPCC Working group 1, and a lead author of AR4 (Chapter 2 – radiative forcing) and AR5 (chapter 7 - aerosols and clouds). He has participated in several major international research efforts, such as IGBP, IGAC, CACGP, IPCC, WMO and others. His scientific expertise is in radiative effects of aerosol particles, focusing on tropical aerosols, biogeochemical cycling in the Amazon basin, physical and chemical properties of biogenic and biomass burning aerosols. He published more than 320 scientific papers and has more than 8000 citations. He is a member of the Brazilian Academy of Sciences and TWAS, the Academy of Sciences of the Developing World. He is a fellow of the American Association for the Advancement of Science. He has received several awards, among them the title of Doctorate of Philosophy Honoris Causa of the University of Stockholm, Sweden.

Clive Hamilton

Clive Hamilton is an Australian author and public intellectual. In June 2008 he was appointed Professor of Public Ethics at the Centre for Applied Philosophy and Public Ethics, a joint centre of Charles Sturt University and the University of Melbourne. For 14 years, until February 2008, he was the Executive Director of The Australia Institute, a progressive think tank he founded. He holds an arts degree from the Australian National University and an economics degree from the University of Sydney. He completed a doctorate at the Institute of Development Studies at the University of Sussex. Before establishing The Australia Institute he taught in the Graduate Program in the Economics of Development at the ANU then joined the Australian Public Service. In recent years he has held visiting academic positions at Yale University, the University of Cambridge and the University of Oxford. He has published on a wide range of subjects but is best known for his books, including Requiem for a Species: Why We Resist the Truth about Climate Change (2010) and Earthmasters: The Dawn of the Age of Climate Engineering (2013).

David Keith

David Keith has worked near the interface between climate science, energy technology, and public policy for twenty-five years. He took first prize in Canada's national physics prize exam, won MIT's prize for excellence in experimental physics, and was one of TIME magazine's Heroes of the Environment. David is Professor of Applied Physics in Harvard's School of Engineering and Applied Sciences and Professor of Public Policy in the Harvard Kennedy School, and founder at Carbon Engineering, a company developing technology to capture of CO_2 from ambient air to make carbon-neutral hydrocarbon fuels. Best known for work on the science, technology, and public policy of solar geoengineering, David is leading the development of an interfaculty research initiative on solar geoengineering at Harvard. David's work has ranged from the climatic impacts of large-scale wind power to an early critique of the prospects for hydrogen fuel. David's hardware engineering projects include the first interferometer for atoms, a high-accuracy infrared spectrometer for NASA's ER-2, and currently, development of CO_2 capture pilot plants for Carbon Engineering. David teaches courses on Science and Technology Policy and on Energy and Environmental Systems where he has reached students worldwide with an online edX course. He has writing for the public with A case for climate engineering from MIT Press. Based in Cambridge, David spends about a third of his time in Canmore Alberta.

Tim Lenton

Tim Lenton is a Professor and Chair in Earth System Science and Climate Change at the University of Exeter. His research focuses on understanding the behaviour of the Earth as a whole system, especially through the development and use of Earth system models. He is particularly interested in how life has reshaped the planet in the past, and what lessons we can draw from this as we proceed to reshape the planet now – as detailed in his book with Andrew Watson on the 'Revolutions that made the Earth' (OUP, 2011). Tim's work identifying the tipping elements in the climate system won the Times Higher Education Award for Research Project of the Year 2008. He has also received a Philip Leverhulme Prize 2004, a European Geosciences Union Outstanding Young Scientist Award 2006, the British Association Charles Lyell Award Lecture 2006, the Geological Society of London William Smith Fund 2008 and a Royal Society Wolfson Research Merit Award 2013.

Jane C.S. Long

Dr. Long was chair of the Task Force on Geoengineering for the Bipartisan Policy Center and chairman of the California Council on Science and Technology's California's Energy Future committee. She serves on the board of directors for the Clean Air Task Force, the Center for Sustainable Shale Development, the Bay Area Air Quality Management District Advisory Board, the Forum for Climate Engineering Assessment Advisory Board, and the Center for Carbon Removal Advisory Board. Dr. Long recently retired from Lawrence Livermore National Laboratory where she was the Principal Associate Director at Large, Fellow in the LLNL Center for Global Strategic Research and the Associate Director for Energy and Environment. She is currently a senior contributing scientist for the Environmental Defense Fund and was the Dean of the Mackay School of Mines, University of Nevada, Reno and Department Chair for the Energy Resources Technology and the Environmental Research Departments at Lawrence Berkeley National Lab. Dr. Long holds a bachelor's degree in engineering from Brown University and Masters and PhD from U. C. Berkeley, is a fellow of the American Association for the Advancement of Science and was named Alum of the Year in 2012 by the Brown University School of Engineering. Dr. Long is an Associate of the National Academies of Science (NAS) and a Senior Fellow and council member of the California Council on Science and Technology (CCST) and the Breakthrough Institute.

Douglas MacMartin

Douglas MacMartin splits his time between Mechanical & Aerospace Engineering at Cornell University, and Computing + Mathematical Sciences at the California Institute of Technology. His research lies at the intersection between engineering feedback analysis and climate dynamics, with a primary focus on solar geoengineering – working to develop the knowledge base for society to make informed decisions. In addition to applying engineering analysis to climate dynamics, he is also involved in control design for the Thirty Meter Telescope. He received his Bachelors' degree from the University of Toronto in 1987, and Ph.D. in Aeronautics and Astronautics from MIT in 1992; prior to joining Caltech in 2000, he led the active control research and development program at United Technologies Research Center.

Oliver Morton

Oliver Morton writes about scientific and technological change and their effects. He concentrates particularly on the understanding and imagining of planetary processes. He is a senior editor at The Economist, responsible for the magazine's briefings and essays. He was previously Chief News and Features Editor at Nature and editor of Wired UK, and has contributed to a wide range of other publications. He writes on subjects from quantum physics to synthetic biology to moviemaking; his articles have been anthologised and won awards. He is the author of three books: Mapping Mars: Science, Imagination and the Birth of a World (2002), which was shortlisted for the Guardian First Book Award; Eating the Sun: How Plants Power the Planet (2007), a book of the year in The Spectator and the Times Literary Supplement; and The Planet Remade: How Geoengineering Could Change the World (2015), longlisted for the Samuel Johnson Prize and shortlisted for the Royal Society Book Prize. In The Sunday Times Bryan Appleyard described it as "ambitious, enthralling and slightly strange". He is an honorary professor in Department of Science, Technology, Engineering and Public Policy at UCL and has a degree in the history and philosophy of science from Cambridge University. He lives with his wife in Greenwich, England, and Asteroid 10716 Olivermorton is named in his honour.

Simon Nicholson

Simon Nicholson is Assistant Professor and Director of the Global Environmental Politics Program in the School of International Service at American University. He is also co-Executive Director of the Forum for Climate Engineering Assessment, a research and public policy group committed to ensuring that the conversation about climate engineering technologies is inclusive and robust, with a focus on the needs of the most vulnerable people and populations. Simon's research and public engagement center around global environmental governance, global food politics, and the environmental and political implications of emerging technologies. His most recent book (edited with Sikina Jinnah) is, "New Earth Politics: Essays from the Anthropocene" (MIT Press, 2016).

Alan Robock

Dr. Alan Robock is a Distinguished Professor of climate science in the Department of Environmental Sciences at Rutgers University. He graduated from the University of Wisconsin, Madison, in 1970 with a B.A. in Meteorology, and from the Massachusetts Institute of Technology with an S.M. in 1974 and Ph.D. in 1977, both in Meteorology. Before graduate school, he served as a Peace Corps Volunteer in the Philippines. He was a professor at the University of Maryland, 1977–1997, and the State Climatologist of Maryland, 1991–1997, before coming to Rutgers. Prof. Robock has published more than 370 articles on his research in the area of climate change, including more than 220 peer-reviewed papers. His areas of expertise include geoengineering, climatic effects of nuclear war, effects of volcanic eruptions on climate, and soil moisture. He serves as Editor of Reviews of Geophysics, the most highly-cited journal in the Earth Sciences. His honors include being a Fellow of the American Geophysical Union, the American Meteorological Society (AMS), and the American Association for the Advancement of Science, and a recipient of the AMS Jule Charney Award. Prof. Robock was a Lead Author of the 2013 Working Group 1 Fifth Assessment Report of the Intergovernmental Panel on Climate Change (awarded the Nobel Peace Prize in 2007). He recently served as a member of the Board of Trustees of the University Corporation for Atmospheric Research, which operates the National Center for Atmospheric Research.

Lynn M. Russell

Lynn M. Russell is Professor of Atmospheric Chemistry at Scripps Institution of Oceanography on the faculty of University of California at San Diego. She completed her undergraduate work at Stanford University. She received a Ph.D. in Chemical Engineering from the California Institute of Technology for her studies of marine aerosols. She was a Professor at Princeton University before joining Scripps. Her research is in the area of aerosol particle chemistry, including the behavior of particles in marine and anthropogenically-influenced conditions. She received the Whitby Award of the American Association of Aerosol Research in 2003 for her contributions on atmospheric aerosol processes.

Pablo Suarez

Pablo Suarez is Associate Director for Research and Innovation at the Red Cross Red Crescent Climate Centre, where he oversees work in Africa and the Americas, leads initiatives linking applied knowledge with humanitarian work, and explores new threats and opportunities on climate risk management (such as geoengineering, financial instruments, or participatory games for learning and dialogue). Pablo is also visiting fellow at Boston University and research scholar at the International Institute for Applied Systems Analysis (IIASA) in Austria. His work as researcher and practitioner focuses on the integration of climate information into decision-making, and on institutional integration across disciplines and geographic scales. He has consulted for the United Nations Development Programme, the World Food Programme, Oxfam America, and about twenty other international humanitarian and development organizations, working in more than 50 countries.

Eduardo Viola

Eduardo Viola holds a Doctorate in Political Science from the University of Sao Paulo (1982) and Post-Doctoral training in international political economy at the University of Colorado at Boulder (1990-91). He has been Full Professor at the Institute of International Relations, University of Brasilia, since 1993 and Senior Researcher of the Brazilian Council for Scientific and Technological Development (CNPq). He is the coordinator of the CNPq Research Group "The International System in the Anthropocene and Climate Change". Dr. Viola has been visiting professor in several international universities, among them: Stanford, Colorado at Boulder, Texas at Austin, Notre Dame, Amsterdam, Campinas and Buenos Aires. Dr. Viola is member of various international scientific committees. Dr. Viola has published eight books, more than eighty peer review articles in journals and more than fifty book chapters in several countries and languages on issues of Globalization and Governance, International Environmental Policy and Politics, Brazilian Climate Policy, and, International Political Economy of Energy and Climate Change.

Annex II: List of Participants

Paulo Artaxo	University of Sao Paulo	Brazil
Christian Baatz	Christian-Albrechts-Universität zu Kiel	Germany
Leo Barasi	European Climate Foundation	Germany
Nnimmo Bassey	Health of Mother Earth Foundation	Nigeria
Rob Bellamy	Oxford University	UK
Ulrike Bernitt	German Research Foundation Priority Program 1689 (DFG SPP)	Germany
Katharina Beyerl	Institute for Advanced Sustainability Studies e. V. (IASS)	Germany
Miranda Boettcher	Institute for Advanced Sustainability Studies e. V. (IASS)	Germany
Lena Boysen	Max Planck Institute for Meteorology	Germany
Thomas Bruhn	Institute for Advanced Sustainability Studies e.V. (IASS)	Germany
Holly Jean Buck	University of California	USA
Martin Bunzl	Rutgers University	USA
Lizzie Burns	Harvard University	USA
Tim Butler	Institute for Advanced Sustainability Studies e. V. (IASS)	Germany
Amy Butler	National Oceanic and Atmospheric Administration (NOAA)	USA
Friedemann Call	Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)	Germany
Sabina Caris	The World Academy of Sciences (TWAS)	Italy
Yann Chavaillaz	Ouranos Inc. & Concordia University, Montreal	Canada
Anthony Chavez	Northern Kentucky University	USA
Ying Chen	Chinese Academy of Social Sciences	China
Amy Ching	Wageningen University	Netherlands
Forrest Clingerman	University of Northern Ohio	USA
Christopher Coenen	Karlsruhe Institute of Technology (KIT)	Germany
Olaf Corry	Copenhagen University	Denmark
Eric Jhon Cruz	University of the Philippines – Los Baños	Philippines
Floyd DesChamps	The Desner Group, LCC	USA
Haomiao Du	University of Twente	Netherlands
Sebastian Eastham	Harvard University	USA
Eric Fee	German Federal Environment Agency	Germany
Miriam Ferrer Gonzalez	Max Planck Institute for Meteorology	Germany
Noam Fischer		Germany
Jane Flegal	University of California, Berkeley	USA
Jim Fleming	Colby College	USA
Peter C. Frumhoff	Union of Concerned Scientists	USA
Lili Fuhr	Heinrich Böll Foundation	Germany
Oliver Geden	Stiftung Wissenschaft und Politik (SWP)	Germany
Arunabha Ghosh	Council for Energy, Environment and Water (CEEW)	India
Cicilia Githaiga	National Environment Management Authority	Kenya
Benjamin Gyampoh	African Academy of Sciences	Kenya
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Hermann Held	University of Hamburg	Germany
Tracy Hester	University of Houston Law Center	USA
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Clare Heyward	University of Warwick	UK
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Anna Maria Hubert	University of Calgary	Canada
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Hugh Hunt	Cambridge University	UK
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Helene Muri	University of Oslo	Norway
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Franz Dietrich Oeste	gM-Ingenieurbüro	Germany
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Wake Smith	New State Capital Partners LLC	USA
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Kelly Wanser	University of Washington	USA
Adrian Omar Watson	Jamaica Environmental Entrepreneurs' Advocacy Network	Jamaica
Philip Williamson	University of East Anglia	UK
Adam Wong	Niskanen Center	USA
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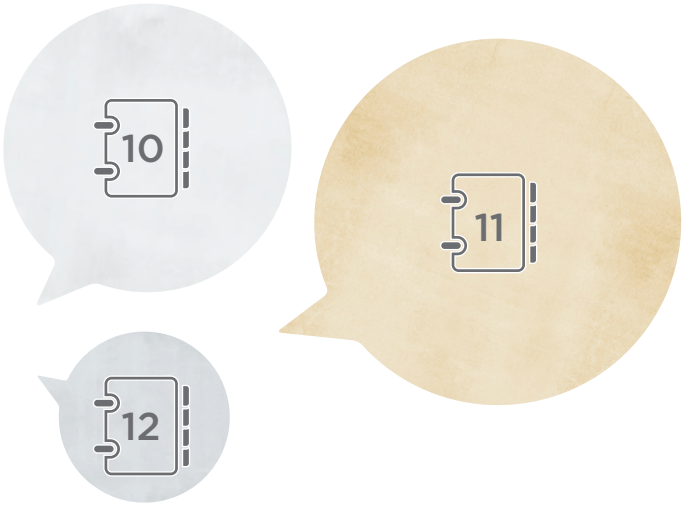
Jiajun Wu	GEOMAR Helmholtz Centre for Ocean Research Kiel	Germany
Wenjiang Zhang	World Meteorological Organisation	China
Zhihong Zhuo	Free University of Berlin	Germany

Annex III:
Conference programme

16:00 – 18:30	CEC17 Registration	
18:30–22:00	CEC17 Opening Event + Reception	Room: 01 I Großer Saal
Tuesday		
09:00–10:30	SRM & CDR updates + ignite-style talks on major projects	Room: 01 I Großer Saal
11:00–12:30	1.1: Communicating Climate Engineering	Room: 02 I Elysium
11:00–12:30	1.2: The Geoengineering Model Intercomparison Project: Where have we been and where should we go?	Room: 01 I Großer Saal
11:00–12:30	1.3: A change of course: Radical emission reduction pathways to stay under 1.5 °C	Room: 04 I Seminar I/II
11:00–12:30	1.4: Achieving the SDGs: Governing Geoengineering in a post-Paris world	Room: 03 I Plenarsaal
14:00–15:30	1.5: The economics of climate engineering: The recent past and the road ahead	Room: 02 I Elysium
14:00–15:30	1.6: SRMGI 1: SRM research across Asia	Room: 04 I Seminarraum I/II
14:00–15:30	1.7: God(s) and Greenhouse Gases: Religion and Climate Engineering	Room: 03 I Plenarsaal
14:00–15:30	1.8: Public Engagement & Climate Engineering: Whither and How?	Room: 01 I Großer Saal
16:00–17:30	1.9: To Gabon or not to Gabon: A game on geoengineering research and policy	Room: 03 I Plenarsaal
16:00–17:30	1.10: Security Risk Pathways of Climate Engineering and Counter-Geoengineering: Conflict or Cooperation?	Room: 04 I Seminarraum I/II
16:00–17:30	1.11: Policy options and principles for negative emissions and SRM	Room: 01 I Großer Saal
16:00–17:30	1.12: Key Elements of Responsible Geoengineering Research	Room: 02 I Elysium
18:30–20:00	Panel discussion at the House of World Cultures: Climate Engineering in the Wake of Paris	
20:00–23:00	Conference dinner at the House of World Cultures	

Plenary ● Parallel session ●



Wednesday

09:00–10:30	2.1: Trumped! A new politics of climate engineering?	Room: 03 I Plenarsaal
09:00–10:30	2.2: Climate engineering: What goes up must come down	Room: 01 I Großer Saal
09:00–10:30	2.3: Climate engineering governance beyond international law	Room: 02 I Elysium
09:00–10:30	2.4: Who needs the Anthropocene?	Room: 04 I Seminarraum I/II
11:00–12:30	2.5: Rational Choice and Worst Case Scenarios	Room: 01 I Großer Saal
11:00–12:30	2.6: Changes of Stratospheric Chemistry and Dynamics and its impacts as a result of climate change and stratospheric aerosol climate engineering	Room: 04 I Seminarraum I/II
11:00–12:30	2.7: Teaching Climate Engineering	Room: 03 I Plenarsaal
11:00–12:30	2.8: Interdisciplinary CDR	Room: 02 I Elysium
14:00–15:30	2.9: SRM Experiments Campfire	Room: 01 I Großer Saal
16:30–18:00	2.10: Climate Engineering Governance World Café	Room: 01 I Großer Saal
18:00–19:30	2.11: Poster session + drinks	Room: Galerie Umweltforum

Thursday

09:00–10:30	3.1: SRMGI 2: How to involve the climate community and the scientific community in debating climate engineering in developing countries?	Room: 02 I Elysium
09:00–10:30	3.2: Geoengineering and the Arctic	Room: 04 I Seminarraum I/II
09:00–10:30	3.3: Two pathways for Sulphate Aerosol Injection. Towards conditions of ethically defensible research and deployment	Room: 03 I Plenarsaal
09:00–10:30	3.4: CE assessment metrics – Comparative, Integrative, Comprehensive	Room: 01 I Großer Saal
11:00–12:30	3.5: The Earth System and Carbon Dioxide Removal	Room: 04 I Seminarraum I/II
11:00–12:30	3.6: A Review of the Recommendations of the Academic Working Group on International Governance of Climate Engineering	Room: 01 I Großer Saal
11:00–12:30	3.7: Modeling, imagining, and making the future in climate engineering	Room: 03 I Plenarsaal
11:00–12:30	3.8: Climate Engineering Research Starting and Stopping Rules	Room: 02 I Elysium
14:00–15:30	3.9: Putting the 'Engineering' in Solar & Carbon Climate Engineering Approaches	Room: 01 I Großer Saal
14:00–15:30	3.10: Campfire Sessions on a Code of Conduct for Geoengineering Research	Room: 04 I Seminarraum I/II
14:00–15:30	3.11: Performative Experiments in Geoengineering	Room: 02 I Elysium
14:00–15:30	3.12: Social Movements & Climate Engineering Justice from the Periphery	Room: 03 I Plenarsaal
16:00–17:30	Town Hall: Looking forward	Room: 01 I Großer Saal

Plenary ● Parallel session ●

Annex IV: Session formats

Standard Panel Session

Panel sessions are a great way to get more than one expert opinion on a topic in a short amount of time. Panels consist of three-to-five people with preferably contradictory opinions discussing a specific topic in a conversation moderated by a session chair. The session should be framed around a clear question, which is introduced by the chair. Each panel member then has 3–5 minutes to give a position statement introducing their opinions. The chair should then facilitate a question and answer session among the panel members (max 1/3 of the session time) before inviting questions from the audience.

Fishbowl Session

Four to five chairs are arranged in an inner circle. This is the fishbowl. The remaining chairs are arranged in concentric circles outside the fishbowl. A few participants are selected to fill the fishbowl, while the rest of the group sits on the chairs outside the fishbowl. One chair is left empty in the fishbowl. The moderator introduces the topic and the participants inside the fishbowl start discussing the topic. The audience outside the fishbowl listens in on the discussion.

Any member of the audience can, at any time, occupy the empty chair and join the fishbowl. When this happens, an existing member of the fishbowl must voluntarily leave the fishbowl and free a chair. The discussion continues with participants frequently entering and leaving the fishbowl. Depending on how large your audience is you can have many audience members spend some time in the fishbowl and take part in the discussion. When time runs out, the fishbowl is closed and the moderator summarizes the discussion.

Campfire Session

Campfire Sessions begin a lot like a traditional presentation, with a speaker (or multiple speakers) at the front of the room presenting an idea to a group of people. After 15 or 20 minutes, however, the focus shifts from the presenter to the audience. The goal is the creation of an open forum in which the attendees generate the majority of the discussion and knowledge sharing. For the remainder of the session, the presenter becomes a facilitator, inviting responses to comments and questions from those around the room and letting the audience dictate the ultimate direction of the conversation. Campfire sessions allow attendees to drive their own learning, listen to multiple perspectives on the same issue, and share experiences with individuals throughout the room. Campfire sessions also lend themselves to networking.

World Café Session

The World Café is a format designed to encourage a flow of conversation between participants, facilitate broad audience participation, and enable a more sustained discussion. Attendees are seated at tables with four-to-six participants per table in an informal, café-style setting. The process begins with a brief introduction and a "big" question, which attendees are asked to discuss (generally for about 15 minutes). Once time is up, all-but-one of the participants from each table move to a different table and repeat the process. The person who stays functions as a "table host" and reviews what was discussed during the previous rounds. Following two-to-three rounds of discussions, key points from each table are presented to the whole group for a final collective discussion.

Speed Geeking Session

A large room is selected as the speed geeking venue. All the presenters are arranged in a large circle along the edge of the room. The remaining members of the audience stand at the center of the room. Ideally there are about 6-7 audience members for each presenter. One person acts as the facilitator.

The facilitator rings a bell to start proceedings. Once proceedings start, the audience splits up into groups and each group goes to one of the presenters. Presenters have 5 minutes to introduce their work and answer questions. At the end of the five minutes, the facilitator rings a bell. At this point, each group moves over to the presenter to their right and the timer starts once more. The session ends when every group has attended all the presentations.

Open Space Session

The approach is most distinctive for its initial lack of an agenda, which sets the stage for the session's participants to create the agenda for themselves. Typically, an "open space" session will begin with short introductions by a single facilitator of the general theme of the session and the "self-organizing" process called "open space." Then the group creates the working agenda, as individuals post their topics on a physical or electronic bulletin board. Each individual "convener" of a breakout group takes responsibility for naming the topic, posting it on the bulletin board, assigning it a space and time to meet, and then later showing up at that space and time, kicking off the conversation, and taking notes. These notes are usually presented back to the group in a final plenary, and or compiled into a proceedings document that is distributed physically or electronically to all participants.

7-14-28 Presentation Session

7-14-28 presentation is a rapid-fire showcase of ideas, innovations, and theories. Speakers have a 7-minute time limit for their talk utilizing a deck of no more than 14 slides that have a minimum 28-point font size for any text. 7-14-28 allows speakers to focus on the essentials of their subject, while offering an audience the chance to enjoy multiple presentations in one sitting.

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