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ORIGINAL PAPER

Rich man's solution? Climate engineering discourses and the marginalization of the Global South

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Abstract
Numerous recent studies project that 'climate engineering' technologies might need to play a major role in the future. Such technologies may carry major risks for developing countries that are often especially vulnerable to, and lack adaptive capacity to deal with, the impacts of such new technologies. In this situation, one would expect that developing countries—especially the least developed countries that are most vulnerable—should play a central role in the emerging discourse on climate engineering. And yet, as this article shows in detail, the discussion about whether and how to engage with these technologies is shaped by experts from just a small set of countries in the Global North. Knowledge production around climate engineering remains heavily dominated by the major research institutions in North America and Europe. Drawing on information from 70 climate engineering events between 2009 and 2017 along with extensive document analysis, the article maps a lack of involvement of developing countries and highlights the degree to which their concerns remain insufficiently represented in politically significant scientific assessment reports. The article concludes by sketching options that developing countries may have to influence the agenda on climate engineering, reflecting on earlier attempts to increase control over novel technologies and influence global agenda setting.

Keywords Climate engineering · Least developed countries · Geoengineering · Climate policy

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1 Introduction

At the 2015 Paris conference on climate change, governments agreed to limit temperature increase to well below 2 °C, aiming for 1.5 °C. The question is now: how to get there? Influential climate models seem to suggest that reaching these targets would require substantial interventions into the earth's natural systems through so-called 'climate engineering' technologies.[1] For example, most of the low-temperature pathways presented in the Intergovernmental Panel on Climate Change's Special Report on 1.5 °C rely on a massive expansion of bioenergy use with subsequent carbon capture and storage, or large-scale afforestation, to extract billions of tonnes of carbon dioxide from the atmosphere. The report's reference to stratospheric aerosol injection (a technology that imitates volcanic eruptions to cool global temperature) as an option to 'temporarily reduce the severity of near-term impacts' in overshoot scenarios further indicates that in mainstream climate science, some form of climate engineering is expected to become part of the response to climate change (Allen et al. 2018, p. 71).

In OECD countries, some of these technologies are already considered as potential climate policies. For example, the United Kingdom has allocated substantial funding to study greenhouse gas removal technologies (Natural Environment Research Council 2018), and Sweden aims to achieve negative emissions after 2045 including through investment in climate projects abroad (Government Offices Sweden 2017). Several United States government agencies (including the Department of Energy, the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration) commissioned a special report on climate intervention that was published by the National Academy of Sciences in 2015 (McNutt et al. 2015a, b). Also major transnational companies like Shell are relying on carbon dioxide removal for scenarios in which they would conform with the 2 °C target (Evans 2018).

Yet, recent studies also show that using bioenergy at the scale suggested would result in major impacts on land use, water availability and loss of natural habitat (Boysen et al. 2017); and stratospheric aerosol injection could impact global precipitation patterns, possibly inducing drought in equatorial regions (Tilmes et al. 2013). Most severely affected by possible negative impacts would be the world's least developed countries. These 47 low-income nations are identified by the United Nations as those with the most severe structural impediments to sustainable development, especially high vulnerability to economic and environmental shocks and particularly limited human assets.[2] It is in these countries where the impacts of environmental change already pose substantial threats to human development (Biermann et al. 2016).

And yet, it was the least developed countries that were central in advocating for the 1.5 °C target. Together with the (partially overlapping) group of small island states, they provided much of the political momentum to adopt the more stringent temperature target of 1.5 °C in the Paris climate negotiations (Brun 2016).

[1] The scientific literature usually divides climate engineering techniques into those that modify reflectivity (so-called solar radiation management) and those that absorb and remove carbon dioxide. Although widely used, this demarcation based only on physical processes obscures some political issues associated with jurisdiction and scale, so that we prefer to speak of individual technologies instead.

[2] The current list of least developed countries (March 2018) is available at https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/ldc_list.pdf.

Given that the least developed countries pushed for this ambitious climate policy goal, how is it then that the global community's most influential scientific reports on climate change suggest solutions that might bring additional risks for them?

In this article, we argue that one part of the answer lies in the composition of the climate science community and its low representation of authors from the Global South. Given the principle of sovereign equality in international law that grants each country the same vote, least developed countries enjoy, just through their numbers, substantial influence in intergovernmental negotiations. Yet, their lack of involvement in climate mitigation science means a lack of voice in formulating climate scenarios and policy options. Because of this, climate engineering options like large-scale afforestation or the massive expansion of bioenergy with subsequent carbon capture and storage are deemed reasonable, despite their potentially negative impact on important concerns of least developed countries. These include ending patterns of growth that thrive on the unsustainable use of public goods, the extraction of natural assets and the exploitation of developing countries' labour (Least Developed Countries Independent Expert Group 2014).

In the following, we give first a brief background to our study and then present our analysis on the representation of least developed countries in climate engineering science, highlighting their lack of voice in the production of knowledge and the limited acknowledgement of their concerns in assessment reports that inform governmental decision-making. We subsequently suggest options that least developed countries could pursue to gain influence on the types of pathways and scenarios that are prioritised in influential scientific arenas.

2 Climate engineering, least developed countries and the long-term global goal

An analysis of the influence of least developed countries in global debates on climate engineering needs to be seen in light of the general evolution of climate science over the last decades. For example, recent analyses of the IPCC show that the composition of authors who contribute to writing IPCC reports is heavily dominated by experts based in Europe and North America. This was blatantly the case for the first IPCC reports in the 1990s (Biermann 2001, 2002), but has not changed much. Evaluating the four assessment reports published between 1990 and 2007, Ho-Lem et al. (2011) found that people from Africa or South America make up only 3.1% of IPCC authors in total, compared to 35.6% and 37.2% from Europe and North America. Also, 45% of all countries—all from the developing world—have *never* had authors contributing in IPCC processes. Corbera et al. (2016) conducted a comparable analysis for the IPCC's fifth assessment report, in which they find a dominance of institutions from the United Kingdom and the United States that act as training sites for authors in working group III (the section of the assessment report that focuses on mitigation in particular). This leads them to conclude that the United States and the United Kingdom are even more dominant than the number of participating authors reported by either of these countries.

Despite the overrepresentation of the Global North in climate science, the policy solutions that are being developed often affect especially developing countries. The highest potential for bioenergy development and industrial forestry, for example, is consistently projected to be in developing countries around the equator (Haberl et al. 2011; Zomer et al. 2008). The same holds for carbon dioxide removal techniques that are not based on

photosynthesis, for instance, mineral weathering that involves industrial scale, open-pit mining of olivine and other silicates (Kohler et al. 2010). Least developed countries, on their part, generally lack financial and institutional capacity, which make them vulnerable to increasing land acquisition by foreign investors. They are also prone to suffer from food insecurity caused by investment in bioenergy crops, regardless of where they are grown (Yengoh and Armah 2015).

High risks for least developed countries also come with other climate engineering technologies, for instance, with stratospheric aerosol injection and its requirement to maintain deployment until carbon dioxide concentrations have been reduced.[3] Some models suggest that stratospheric aerosol injections would influence precipitation patterns and reduce rainfall in areas that rely on the monsoon and that reducing such variations in precipitation would require 'overcooling of the tropics', hence even more deployment in equatorial regions (MacMartin et al. 2013). Although stratospheric aerosol injection is a comparatively cheap technology to deploy, its effective continuous deployment requires money, technological capability as well as effective command of territory and some degree of global power (Parson 2014). Given these requirements, smaller developing countries are unlikely to be able to actively use stratospheric aerosol injection themselves. Using stratospheric aerosols to limit global temperature rise would hence create a century-long dependence on those governments that do have the necessary means for such interventions. This dependency on powerful actors and their decisions on where and how to deploy stratospheric aerosol injection would run counter to some of the post-2015 Sustainable Development Goals that least developed countries have prioritised, in particular addressing the highly imbalanced political economy and fostering democratic systems to manage public goods from the local to the global level (Least Developed Countries Independent Expert Group 2014).

Despite all these side effects, developing countries might decide that some form of climate engineering is in their interest. In a recent comment in *Nature*, academics from Bangladesh, Brazil and Ethiopia rejected the 'paternalistic' advice provided by some non-governmental groups that advocate against climate engineering technologies because of its implications for Africa. They argue that there is only so much that developing countries can do to advance mitigation and that the primary actors on this front are in the Global North. If temperatures keep rising, the benefits of stratospheric aerosol injection may outweigh its drawbacks (Rahman et al. 2018). In their study of non-western perspectives, Carr and Yung (2018) come to a similar conclusion. Based on interviews with environmental professionals from the South Pacific, Sub-Saharan Africa and the North American Arctic, they find that people who are highly vulnerable to climate change might be willing to consider stratospheric aerosol injection, but that their acceptance is characterised as 'deeply reluctant and highly conditional' and must be understood in the context of frustrations with the current lack of mitigation.

In short, the stakes for least developed countries are high. If the Paris temperature targets are not reached due to lacking reform measures in the Global North and more wealthy parts of the Global South, then least developed countries might face a difficult choice:

[3] If stratospheric aerosol injection were deployed while greenhouse gases continued to accumulate in the atmosphere, and then abruptly stopped, global temperatures would rise dramatically in a short period of time. This would lead to what has been called a global 'termination shock' that would be catastrophic for natural ecosystems and human institutions (Jones et al. 2013).

between the risks of drastic climatic change and the risks of supporting climate engineering by powerful industrialised countries.

Yet, what is their role in current debates? How are they involved, to what extent are their views and concerns represented and through what means could they influence the climate engineering discourse? These questions are of great importance, particularly under the consideration that science and the epistemic communities that produce it play a fundamental role in shaping the 'realities' that inform world politics (Antoniades 2003). The way that climate engineering is defined and the questions that are being asked are already shaped by some countries in the Global North, not least by their authoritative scientific bodies (Belter and Seidel 2013; Gupta and Möller 2018).

In the remainder of this article, we analyse the degree and types of involvement of representatives of developing countries, especially least developed countries, in discursive networks around climate engineering. We look at both the discursive process and the discursive content. We study the process by analysing representation in the epistemic community around climate engineering, understood as the community of experts actively involved in producing knowledge on the subject and fostering interest for their community's policy project (Antoniades 2003). We study the content by evaluating the climate engineering discourse in areas where science is expected to have high impact on policy. These are best captured in scientific assessment reports and in the reports of science policy workshops in the Global South.

3 Representation in the discursive process

To assess representation in the discursive process, we analysed lists of speakers at climate engineering events and the organisations that they are affiliated with. These events were identified with the help of climate engineering newsletters (including the 'Geoengineering Google Group' and the 'Climate Engineering Newsletter' distributed by the Kiel Earth Institute), snowballing on from there to look for further activity of any mentioned research projects.[4] We identified 84 events related to climate engineering that took place between 2009 and 2017: 75% in OECD countries (of which three-thirds were in the United Kingdom, the United States and Germany); 13% in the group of the so-called BRICS countries (Brazil, Russia, India, China and South Africa); and 12% in developing countries. Out of these 84 events, 70 provided information about the programme and were thus included in our further analyses.[5] (Those that did not provide information reflected the same geographic proportions as the events overall.) The resulting database contains 1263 speakers, which can be aggregated into 779 individuals. 208 of these individuals spoke at more than one event, indicating a relatively small active epistemic community.

For each speaker, we recorded their (self-reported) affiliation and coded these organisations according to the country in which it is based. We then calculated the distribution

[4] Because these newsletters are published in English or German, we may not have captured all climate engineering events in this period. The focus of the newsletters on 'climate engineering' or 'geoengineering' means that events on the expansion of bioenergy use with carbon capture and storage or negative emissions [terms that originated in the context of integrated assessment models and a different epistemic community (Haikola et al. 2018)] are possibly underrepresented.

[5] Our choice to begin with 2009 was motivated by the simultaneous appearance of the 1.5 °C target on the global agenda and the publication of the Royal Society report on Geoengineering governance. This transported the marginal topic of climate engineering into a wider debate on climate science (Owen 2014). 2017 provides the end year of our analysis.

of countries based on institutions that appeared more than once in the database, signifying substantial involvement. Our use of organisations to measure country representation is partly motivated by theoretical and partly by practical reasons. The institutions in which researchers work play an important part in their scientific socialisation and the research they engage with (see also Corbera et al. (2016)). It is therefore worth looking at where the research is being produced rather than focusing on the nationalities of researchers. Furthermore, coding researcher nationality is a difficult endeavour that entails the collection of personal information, while not necessarily providing insights important to the research question overall.

Figure 1 provides descriptive statistics about the geographical origin of organisations represented at climate engineering events. For each year, the graph distinguishes between researchers based at organisations in OECD countries (1), BRICS countries (Brazil, Russia, India, China and South Africa) (2) and developing countries (3). Importantly for our study, in all workshops, no active member from an organisation based in a least developed country was represented; because the value for 'least developed countries' would have been consistently zero, we excluded it from the graph that we present here.

In each group, the stacked colours signify different countries. The dominance of pink, turquoise and olive in the OECD group shows that most organisations we coded are based in the United States, the United Kingdom and Germany (47, 42 and 22, respectively). These are followed (with a sizeable gap) by the Netherlands, Canada and Australia. Overall, OECD countries are overwhelmingly represented. From the BRICS countries, China, India and Brazil have each 3–4 active organisations in our database. The other developing countries show much less involvement, with only 12 organisations distributed across Fiji, Indonesia, Jamaica, Kenya, Singapore and Thailand.

Out of the organisations based in a developing country, those that were represented as speakers at more than one event were the African Academy of Sciences, the University of Nairobi, Kenyatta University, the University of the South Pacific, the Indonesian Ministry for Energy and Mineral Resources and the National Science Museum of Thailand. However, their representation is comparatively small. Whereas these organisations participate with 2–3 people each, the best represented institutions in the OECD group (the Institute for Advanced Sustainability Studies in Germany, Oxford University and Harvard University) participate with teams of 10–17 people each. For comparison, the best represented organisations in the BRICS group (the Council for Energy, Environment and Water in India, Beijing Normal University, the Chinese Academy of Sciences and the University of Sao Paulo) participate with 3–6 researchers each.

Importantly, the nine developing country events we identified were always initiated and/or co-hosted by a European organisation. The Solar Radiation Management Governance Initiative, the Institute for Advanced Sustainability Studies in Germany and the International Institute for Applied Systems Analysis in Austria have been particularly active in this regard. Their work towards heightening inclusion from developing countries has, among others, resulted in the initiation of the 'DECIMALS' fund. Financed by the United States-based Open Philanthropy Project, the fund supports developing country researchers to study the potential impacts of solar radiation management in their region by using modelling data from initiatives like the Geoengineering Model Intercomparison Project (Solar Radiation Management Governance Initiative 2018). Similar research support for other types of enquiry is, as far as we are aware of, not yet available.

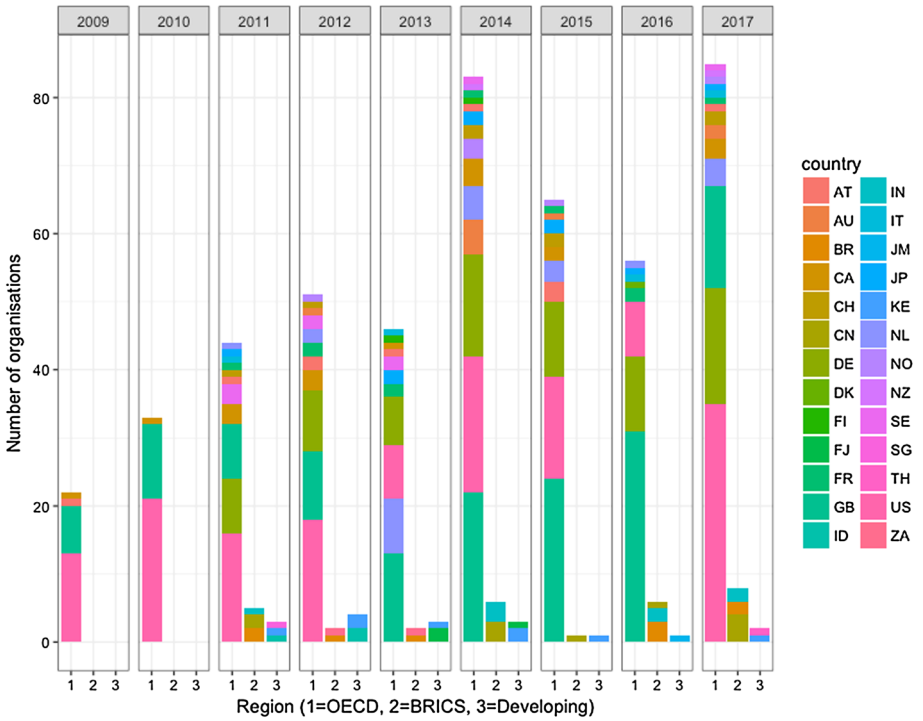

Fig. 1 Distribution of countries in the climate engineering discursive process, based on institutions represented at more than one climate engineering event (in the capacity of speakers). Countries are coded based on the International Naming Convention

Two caveats are to be added to our findings: first, our results represent only events that were held, or referred to, in the English language and might hence under-represent developments in a non-OECD context, such as in China. Second, we coded the geographical affiliation of speakers according to their home institution and not their nationality or country of origin, which is likely to overrepresent European and North American discursive input.

Overall, we conclude that North American and European actors heavily dominate the debate on climate engineering and that efforts to increase participation of developing countries so far largely resulted in a one-way information transfer from North to South rather than a dialogue that takes place on equal footing. Considering the technical nature of climate engineering and the early stages of these debates, such results do not come as a surprise. The idea to engineer the climate in response to global warming was brought onto a scientific agenda by actors in the global North (notably in the United States) and still constitutes a foreign concept to many people in the world. Meanwhile, scientific and political capacities in least developed countries are already stretched, and resources that are available for issues related to climate change are allocated to more pressing questions of adaptation and emergency management. The current low level of involvement of developing countries, and particular least developed countries, in this debate seems hence less a consequence of purposeful exclusion than of persistent structural inequalities in global science—which makes the situation no less problematic.

4 Representation in the discursive content

How does this low representation affect the content of current climate engineering discourses? How are the aspirations and voices of developing countries, in particular those of the least developed countries, represented in climate engineering science? How are their interests, special circumstances and vulnerabilities addressed? We studied this question by conducting a detailed content analysis of reports that have emerged out of the epistemic community on climate engineering. First, we studied the representation of interests of developing and least developed countries in two major climate engineering assessments conducted by interdisciplinary research groups in Europe and the United States. Second, we analysed the content of those few reports that have resulted from workshops that focused on developing countries and/or that were held in a developing country, looking for key interests and concerns on climate engineering from a developing country perspective. In all cases, we studied not only the content of the reports but also the overall context, including data on participation in the production of the report, its mandate and any sponsoring organisations. While our main research focus is representation of the 47 least developed countries, we employed for practical reasons a wider definition in our content analysis and looked also at general references to 'developing countries' or 'poorer countries'.

We identify the degree of marginalisation of the concerns of least developed countries based on four indicators, which we derived from general position papers of least developed countries in multilateral negotiations:

1. *Vulnerability* First, we scrutinised the texts with a view to explicit considerations for the special concerns of least developed countries relating to their high poverty, limited human assets and high economic vulnerability. To what extent are implicit or explicit risk assessments in climate engineering discourses cognizant of the particularly high vulnerability of the least developed countries?
2. *Role acknowledgement* Second, we analysed how the role of least developed countries is described in the reporting (to the extent that they are explicitly mentioned). Are they presented as active stakeholders in research and decision-making; are they rather seen as passive onlookers; or are they not mentioned at all?
3. *Decision-making and governance* Third, recent discourses on climate engineering engaged in initial debates on governance and decision-making regarding such technologies. In general, least developed countries in United Nations negotiations prefer multilateral decision-making based on sovereign equality and effective involvement of all countries, as opposed to, for instance, more restricted international fora such as the Group of 8, or fora with weighted voted such as the World Bank. We hence scrutinised the texts with regards to how suggested modes of decision-making and governance of climate engineering (if any) refer to multilateral institutions where least developed countries have some influence and voting power (such as the United Nations) or rather refer to 'minilateral' modes of governance (for example by centring on the Group of 7 or the Group of 20) or to private modes of governance that build on the leadership of major corporations or scientific organisations dominated by Northern countries.
4. *Equity* Fourth, we analysed the texts regarding possible discussions on questions of global equity, justice and fairness, an issue consistently emphasised by representatives of least developed countries in international negotiations. While there is no generally accepted theory or understanding of global justice despite a lively debate in this field,

we were curious to what extent the analysed documents would pay any attention to such ethical questions in the first place, and what the respective conclusions were.

4.1 Mainstream documents on climate engineering

To answer these questions, we first analysed central documents of the climate engineering debate, focusing on two of the most extensive assessments on climate engineering: the 2015 European Transdisciplinary Assessment of Climate Engineering (EuTRACE) (Schäfer et al. 2015) and the 2015 Climate Intervention assessment conducted by the United States National Academy of Sciences (McNutt et al. 2015a, b). The EuTRACE report presents results from a 2-year, EU-funded project that brought together experts from 14 European institutions. In 170 pages, it informs the European Commission on how climate engineering could relate to its ambitious climate targets. The National Academy of Sciences report is a two-volume document of 375 pages on climate intervention techniques, presenting the results of a 2-year enquiry mandated by the US government. Our choice of these reports is motivated by their comprehensive approach and their direct relevance to policy making. Similar to the IPCC assessment reports, these documents are compiled by large groups of researchers that aim to create a state-of-the-art overview for decision-makers.

Overall, the EuTRACE report evidences a lack of attention for what large-scale climate engineering technologies might imply for the livelihoods of the world's poorest. Only indirectly does it refer to risks and resource demands in developing countries, for instance, by pointing out issues like land use competition and enhanced effectiveness of some techniques in places that have 'favourable conditions' (which, upon closer inspection of the cited sources, are often in equatorial regions). In a few cases, it mentions geographical regions like the Amazon and the Sahel, which would suffer disproportionally from certain types of solar radiation management. Regarding the political representation of developing countries, the report acknowledges that international decision-making is prone to excluding or marginalising those who are particularly vulnerable and mentions procedural norms as a way towards overcoming these difficulties. It also points out that transparency is an important instrument to create legitimacy for research, stating that an independent international or regional body would be required to assess the desirability of outdoor experimentation. It then goes on, however, to suggest that regional and national levels might be more appropriate in thinking about climate engineering governance.

Equity, fairness and justice is understood in this report mostly in terms of inter-generational equity, although reference is made to the prospect of 'distributional conflicts' that might arise when it comes to cost-sharing and risk distribution associated with climate engineering (Schäfer et al. 2015, p. 74). In one instance, the report mentions that 'those geographically and economically most vulnerable to climate change, often living at the subsistence level, would be most likely affected by uneven effects of SAI [stratospheric aerosol injection]' (Schäfer et al. 2015, p. 77). Similarly, the issue of increasing food prices is mentioned only twice in the context of land conversion and the use of bioenergy with carbon capture and storage. Another fairness issue that the report briefly reflects upon is compensation, essentially concluding that the attribution of cause and effect for a working compensation mechanism would be short of impossible. Despite a number of these indirect hints at risks and resources that might be particularly important for least developed countries, overall the report lacks attention for the inherent inequalities and power imbalances that any large-scale climate engineering endeavour would entail.

Compared with the European EuTRACE report, the National Academy of Sciences report places carbon dioxide removal techniques more explicitly into the context of climate change mitigation and adaptation. It also takes a much less critical stance concerning feasibility and potential side effects of this technology group, repeatedly writing that many forms of carbon dioxide removal are benign and do not pose novel risks or governance issues. Its estimates for the potential of such techniques to absorb carbon dioxide are consistently higher than that of the EuTRACE report, and although it recognises that the 'benign' methods of afforestation and the use of bioenergy with carbon capture and storage will require massive amounts of land and could create significant competition with food production, the most outspoken criticism of the approach merely is that 'land management approaches—including afforestation, reforestation and bioenergy production—have the potential to initiate debates over land use' (McNutt et al. 2015a, p. 98). The special interests or vulnerabilities of developing countries and least developed countries are not addressed, although all carbon dioxide removal techniques are assessed on a global level and repeatedly emphasise the tropics as an area of high potential.

Governance of carbon dioxide removal is omitted entirely, apart from suggestions for national bodies that could play a role for governing research in the United States. Developing countries are only mentioned in the context of climate change posing a global challenge in which many nations will have to do their share. Most explicitly, the report states that 'the social context [of carbon dioxide removal] is less about understanding how one set of actions affects the global climate or large numbers of people in the short term and more about how to mobilise multiple nations to engage in a coordinated effort' (McNutt et al. 2015a, p. 99).

Methods to modify the planet's albedo are discussed in the second climate intervention report by the National Academy of Sciences. Vulnerabilities of developing and least developed countries are addressed in the context of a warming climate, stating that while industrialised economies may be able to adapt to climate change, 'the outlook is more pessimistic for the less industrialised societies and economies of the world, and grimmer still for many natural terrestrial, aquatic and oceanic ecosystems' (McNutt et al. 2015b, p. 20). This vulnerability is used as one of the main reasons for which research on albedo modification should be conducted, outlining a scenario in which crop failure in the tropics could lead to 'intense pressure to temporarily reduce temperatures to provide additional time for adaptation' and a possible ensuing deployment of albedo modification in the absence of sufficient knowledge about the technology (McNutt et al. 2015b, p. 32).

Developing countries are not assigned an active role in this report. Instead, the United States is portrayed as a norm entrepreneur that could provide a model for researchers and funding agencies in other countries. It is assumed that only economically powerful countries could initiate an attempt at unilateral ('unsanctioned') albedo modification in the first place, and China as well as India are discussed in terms of regional climate engineering. Simultaneously, the report makes clear that 'governance' does not equate 'regulation' and that a lack of explicit national or international regulation should not necessarily stand in the way of smaller-scale research.

The ethical section of the report mentions the 'additional ethics issues' that arise from the imposition of those who deploy albedo modification measures on those who have no say and who may not favour the deployment. In the wake of this observation, the report points out further need for research on who should have decision-making power and capacity. The explicit inclusion of the 'marginalised, vulnerable and voiceless populations' described earlier and the need to consult them is not expressed.

4.2 Documents from workshops held in the South

Several workshops on climate engineering have been held in developing countries in recent years. How are the least developed countries and their interests framed in documents that emerged from these few workshops? We analysed here in detail the content of reports that have resulted from six workshops that focused on developing countries and/or that were held in a developing country.

Africa In Africa, we studied three workshops on climate engineering that were organised in a collaborative effort of the African Academy of Sciences and the Solar Radiation Management Governance Initiative: on 27 June 2012 in Dakar, Senegal, on 'Governance of Solar Radiation Management Research: African Perspectives'; on 28 September 2012 in Boksburg, South Africa, on 'Solar Geoengineering: Research, Governance, and African Involvement', and on 14 January 2013 in Addis Ababa, Ethiopia, on 'African Involvement in Solar Geoengineering'. All together, these workshops were attended by about hundred participants from 21 African (mostly least developed) countries; most participants were scientists. All workshops discussed solar radiation management only; their results were summarised in a single report (African Academy of Sciences and Solar Radiation Management Governance Initiative 2013). (We are not aware of comparable events in Africa on carbon dioxide removal.)

The meetings all began with introductions to climate change in Africa (given by a South Africa-based expert) and to the idea of solar radiation management (given by a United Kingdom- or United States-based expert). The lectures were followed by an exercise with pre-formulated scenarios, which participants were asked to rate on a scale from desired facilitation to desired prohibition. Although participation was encouraged, the workshops seemed to rely very much on the information presented by Northern experts to the audience, rather than fostering free engagement with various sources.

While different views were expressed during these exercises, several common themes and concerns can be identified, most of which differ from the mainstream North American or European reports. First, participants highlighted several special African concerns, notably the risks to African agriculture and regional differences in impacts. In addition, participants stated that alternative approaches such as reforestation and afforestation are not discussed sufficiently. Overall, the workshops revealed the widespread perception of lack of capacity and knowledge in Africa to effectively engage in global debates on this novel set of technologies. These concerns are reflected in the roles that participants foresee for Africa, which are largely focused on African scientists as contributors in research programmes and as experts who inform their governments. The framing is likely to be influenced by the selection of participants, who largely represented the African science community with few government officials or civil society representatives involved.

Participants also expressed views about the modes of global governance that should regulate the debate, if not deployment, of climate engineering technologies. For one, participants saw an important role for African countries to continue pushing industrialised countries to increase efforts towards decarbonisation, hence making climate engineering unnecessary in the first place. In addition, the African discourse seems to suggest a preference for strong global institutions, for instance an independent and transparent international body to regulate outdoor solar radiation management experimentation, either through the World Meteorological Organization, installed through the UN Security Council, or independently. More generally, African experts argued in favour of a strong role of the African Union; stronger facilitation by universities and governments for indoor research; full

transparency of involved researchers and related funding mechanisms; and the bottom-up involvement of developing countries.

Asia and Pacific In Asia, we study two expert workshops, the first of which was held in 2011 in Singapore on 'Governing Geoengineering in the Twenty-first Century: Asian Perspectives', organised by the S. Rajaratnam School of International Studies Centre for Non-Traditional Security Studies, the Oxford Geoengineering Programme and the Solar Radiation Management Governance Initiative (RSIS Centre for Non-Traditional Security Studies 2011). The agenda of this small workshop on supposedly 'Asian Perspectives' was highly dominated by speakers from the North, from the universities of Oxford, Leeds, Southampton and Tokyo, and the United States-based Environmental Defense Fund, with additional videoconferencing with panel members of the British Royal Society. Asian experts seem to have spoken in plenary only in one session on country perspectives, and a session on civil society perspectives. The other participants of the workshop—only 13 names are listed—are largely representatives from Singaporean agencies. Despite its broad title, by no means can this workshop be characterised as a comprehensive, open discussion of perspectives from Asia and the Pacific. The report that has been made available after the workshop should hence be seen largely as a compilation of views from the experts from the United Kingdom and the United States, possibly influenced by comments from the Singaporeans—but not as an original contribution of Asian perspectives.

A second event was held in New Delhi, India, in 2014, organised jointly by the Council on Energy, Environment and Water (an Indian policy research institution) and the Institute for Science, Innovation and Society at the University of Oxford, United Kingdom. Given the strong role of the Indian organisers—and presumably the Council's influential chairperson, Suresh Prabhu, and other internationally leading Indian experts—the meeting saw a much stronger presence and participation of Southern voices compared to the other workshops held in developing countries. Possibly as a result, the workshop report is more focused on considerations of equity and global justice, with the report's summary even ending with a statement to the effect that the principles of equity and common but differentiated responsibilities 'will be of concern to many countries involved in action against anthropogenic climate change, including India' (Council on Energy Environment and Water 2014, p. 16). It also appears that the conference overall veered towards a more critical stance vis-à-vis some of these technologies, arguing in the report among others that, 'Due to lack of opt-out option, issues in delineating research from deployment and concerns of possible militarisation and regional destabilisation, few saw SAI [stratospheric aerosol injection] as governable' (Council on Energy Environment and Water 2014, p. 16).

In addition, one workshop—held in August 2013 in Suva, Fiji—addressed the situation of the Pacific islands (Beyerl and Maas 2014). The workshop was co-hosted by the Pacific Centre for Environment and Sustainable Development at the University of the South Pacific and the Institute for Advanced Sustainability Studies in Potsdam, Germany. About 40 experts participated, a third of whom were faculty and students from the Pacific Centre in Fiji. Other participants included representatives from science, civil society, religious organisations and governments in the region, along with four members of the United States embassy and USAID. The workshop proceedings evidence a unidirectional flow of information, with all substantive presentations being made by the German experts. Discussions with representatives from the region revealed a number of key concerns, notably the urge to focus, first, on mitigation, the need to adopt a precautionary approach and for 'regulatory and enforceable governance structures' before any significant field testing and implementation of climate engineering technologies' can be done. Overall, experts in Pacific island states seem to be largely uninformed and disconnected with the emerging

climate engineering discourse in the North, and unprepared so far to develop a strong policy position.

5 Conclusions and policy implications

Climate engineering technologies are not yet developed and remain far from being deployed. Yet, the current state of global climate governance has given rise to a new, rapidly growing discourse—one that may turn climate engineering into a legitimate climate governance option. If deployed, climate engineering technologies are likely to have tremendous impacts on developing countries. And yet, many climate engineering technologies could be deployed by a limited group of industrialised countries without global consent. All this makes the growing climate engineering discourse a vital policy issue for developing countries, especially the least developing countries where, in a few decades, one-fifth of humanity might live.

Our analysis has shown that the pivotal importance of this issue is not reflected in a strong and meaningful role of least developed countries in the current climate engineering debate. Almost all expert workshops and conferences are held in the North, and almost all experts involved are residents of a few industrialised countries. The few workshops in the South that we identified are again largely dominated by speakers from a few industrialised countries and often give the impression of a rather unidirectional flow of views from North to South. A global discourse and epistemic community is taking shape that might chart the way towards the largest purposeful alteration of planetary systems ever imagined by people—yet this discourse is at present still driven and increasingly legitimized by only few countries in the North.

What are then the policy options for least developed countries to raise their voice? Recent history provides numerous examples where developing countries tried to gain control over new technologies developed in the North, and over the gains from novel resources and industries. In most of these cases, control was eventually retained by the most powerful countries that could exploit the resource or maintain the activity in question. It remains to be seen whether the emerging field of climate engineering will be different. At present, we see four avenues at the level of international politics along which least developed countries could seek to increase their influence on discussions on, and possibly development of, climate engineering technologies.

(1) Increasing Control of Global Science Networks First, least developed countries could seek a stronger role in the emerging epistemic communities on climate engineering. Governments and science institutions of least developed countries could request more involvement in meetings and conferences, reports and briefings, including more financial support to enable such participation. One example could be the IPCC model, in which working groups generally have one co-chair from a Southern country (Biermann 2002). While such increased participation might also lead to false impressions of legitimacy by adding 'a few Southern names' without factually increasing the influence of Southern experts, more participation might also help bring forward the concerns, interests and risks that are most important from a least developed country perspective, including in discourses that might shape the future governance modes on climate engineering.

(2) Calling for a Regulatory Authority in the United Nations System Given the vast imbalances between North and South in terms of research facilities and scientific resources, it is unlikely that Southern interests and voices will easily influence the debates on climate

engineering as they are currently unfolding in the major academic centres in the North. For that reason, governments of least developed countries could try to increase their influence on the emerging discourses on climate engineering outside the confines of expert meetings and scientific programmes. This would include raising the issue in the multilateral institutions where their voice matters, notably the United Nations. One option could be the establishment of a global control and approval mechanism that would regulate or ban all unilateral activities in this domain pursued by individual states or private actors. Such a mechanism could involve—as proposed for instance by African experts at workshops discussed above—a veto right of African countries on any decisions. It would also reflect the suggestions of experts from the Pacific islands, who state that consultations with their governments should be 'mandatory, regardless of whether an individual country is a party or member to any treaty instrument that would make decisions on climate engineering' (Beyerl and Maas 2014, p. 16).

To advance a global approval mechanism under (largely) Southern control, governments of least developed countries could table the issue in the United Nations General Assembly, where they collectively combine about 25% of the votes. If joined by other developing countries not classified as least developed countries, they could easily reach an absolute majority. Pacific island experts have already indicated the need 'to form a unified voice and voting in assemblies like the UN' on climate engineering (Beyerl and Maas 2014, 14), which is likely to quickly generate voting majorities in many multilateral institutions. While the General Assembly cannot take binding decisions, its resolutions can have important normative effects, representing public evidence of broad consensus on an issue. Similarly, the General Assembly could express concerns with (certain elements) of the climate engineering debate; decide on a global (non-binding) moratorium; or agree on the establishment of a Global Geoengineering Authority. Such measures would formally not require the consent of the few technologically advanced countries that have the means to deploy climate engineering technologies. While least developed countries cannot enforce a UN declaration or multilateral agreement upon major industrialised powers, their organised resistance, for instance by means of a UN General Assembly declaration, can exert pressure that raises the political costs for any country that might consider unilateral deployment of climate engineering technologies in the future.

(3) Taking Action through Multilateral Environmental Agreements Third, least developed countries could table the issue in the conferences of the parties to multilateral agreements that might relate to this subject matter. An example of this already took place in 2010, when a coalition of oceanographers and advocates convinced the Convention on Biological Diversity to limit experimentation on ocean fertilisation, the first carbon dioxide removal technology to be widely discussed. Following from this, parties to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter adopted an amendment that sets up a legally binding mechanism to regulate ocean fertilisation and possibly other future marine climate engineering activities (Fuentes-George 2017). A similar pathway could be open to least developed countries also for other climate engineering mechanisms and under other multilateral agreements.

(4) Taking Cases to the International Court of Justice Fourth, least developed countries could push for a decision on the legality of the deployment of certain climate engineering technologies before the International Court of Justice. A formal judgement is only possible in a legal conflict among states where both states agree on adjudication of the Court—which might be unlikely for conflicts around climate engineering. On the other hand, the Court can issue advisory opinions if requested to do so by an international organisation, such as the World Health Organization.

These four policy options that we sketch might help developing countries, and in particular least developed countries, to regain control over their future with regard to the emerging climate engineering discourse. We see an opportunity for them to take the lead on climate engineering in all multilateral institutions where their voice counts and their vote matters, from the UN General Assembly to the treaty bodies under environmental, marine or outer space regimes. Injecting aerosols in the stratosphere or claiming large parts of African land for carbon dioxide removal are not simply new technologies, the development of which can be left to few experts, funders and companies in the former colonial capitals in the North. Such approaches fundamentally affect the entire earth system and—if something goes wrong—might threaten the life of millions of people, and especially the poor. Urgent action at the multilateral level might be needed for developing countries to increase their influence in this rapidly emerging debate.

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