Carnegie Climate
Geoengineering
Governance Initiative

An initiative of the
CARNEGIE COUNCIL for Ethics in International Affairs

Geoengineering:
the need for governance

February 2019

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Acknowledgements:

The paper was prepared and published by the Carnegie Climate Geoengineering Governance Initiative (C2G2) which is an initiative of the Carnegie Council for Ethics in International Affairs. Any views expressed in this paper are solely those of its authors, and do not reflect any official position.

The authors would like to express their gratitude to Neth Daño of ETC Group, members the C2G2 team and eight anonymous independent reviewers for their much-appreciated comments and suggestions which improved the content of this paper.

Suggested citation:

C2G2 (2019). Geoengineering: the need for governance. Carnegie Climate Geoengineering Governance Initiative (C2G2), February 2019, New York, USA.

www.c2g2.net

What is geoengineering and why does it need governing?

In recent reports by the Intergovernmental Panel on Climate Change[1,2], consideration has been given to two approaches to alleviate the impacts of climate change which are often referred to as 'geoengineering'. They include mitigation measures such as large-scale Carbon Dioxide Removal and remediative measures known as Solar Radiation Modification. Both approaches face uncertainties around feasibility, acceptability, sustainability and governance. So, what exactly is geoengineering and why does it need governing?

Geoengineering refers to a broad set of methods and technologies that aim to deliberately alter the climate system on a sufficiently large scale to alleviate the impacts of climate change[3]. While definitions and terminology vary, in line with recent scientific consensus this paper gives separate consideration to the two main approaches considered as geoengineering: Solar Radiation Modification (SRM) and large-scale Carbon Dioxide Removal (CDR).

Over the past decade, the idea of intentionally trying to engineer the earth's climate has begun to receive increasing attention from academics[4,5], national institutions[6,7,8], governments[9,10] and intergovernmental organisations[11,12,13,14,15]. The Intergovernmental Panel on Climate Change (IPCC) included SRM and CDR in its fifth assessment report[16] and is expected to dedicate more attention in its forthcoming sixth assessment report (due in 2022)[11].

What is geoengineering?

Geoengineering is an umbrella term used to refer to a range of existing, experimental and theoretical technologies that aim to help manage global climate risk in a variety of ways, with distinct implications for governance. In this paper, in line with the IPCC, we address these technologies under two broad categories: Carbon Dioxide Removal and Solar Radiation Modification.

Carbon Dioxide Removal (CDR) aims to reduce atmospheric concentrations of Carbon Dioxide (CO_2) and other greenhouse gases through processes that remove it from the atmosphere by either increasing biological sinks of CO_2 or using chemical processes to directly bind CO_2. CDR is classified by the IPCC as a special type of mitigation[4]. CDR is not necessarily considered as geoengineering, however, the concept of deploying CDR at sufficiently large scale to alter the climate is sometimes referred to as geoengineering, although the use of the term in this context is not universally accepted. Other commonly used terms include Greenhouse Gas Removal, Negative Emissions Technologies or Carbon Geoengineering. Most IPCC scenarios that are expected to keep global warming within 1.5-2°C already assume widespread deployment of some kinds of CO_2 removal while acknowledging that the technologies and methods are uncertain and to varying degrees associated with challenges and risks[18, 17].

Solar Radiation Modification (SRM) refers to methods that aim to reduce global warming by reflecting more solar radiation into space or by allowing more heat to escape the earth's atmosphere. The IPCC have previously referred to it as Solar Radiation Management[27] while other commonly used terms include: Albedo Enhancement or Modification; Radiation Modification Measures; Radiative Forcing Geoengineering; Solar Geoengineering or simply, Geoengineering. Many conceptual ideas for SRM measures exist, most of which have not yet progressed beyond the journal article, computer model or laboratory stage. Stratospheric Aerosol Injection (SAI) is the most researched method with other less well-researched approaches including Ground-Based Albedo Modification, Marine Cloud Brightening or Cirrus Cloud Thinning[4].

In its recent special report on global warming of 1.5°C, the IPCC noted that all modelled pathways limiting global warming to 1.5°C with limited or no overshoot, project the use of CDR at a large scale[17]. The report goes on to highlight that most current and potential CDR measures could have significant impacts on land, energy, water, or nutrients if deployed at large scale. Furthermore, it notes that afforestation and bioenergy in particular may compete with other land-uses, may have significant impacts on agricultural and food systems, biodiversity and other ecosystem functions and services, and would require governance systems if deployed at large scale[18]. In relation to SRM, the IPCC notes that although some SRM measures may be theoretically effective[19], they face large uncertainties, knowledge gaps and substantial risks, institutional and social constraints to deployment related to governance, ethics and impacts on sustainable development[18].

Concerns also exist that exploration of large-scale CDR or SRM could potentially divert interest or investment away from greenhouse gas emissions mitigation[20], and some scholars have suggested that even researching some technologies could lead to political or institutional lock-in to deployment[21]. While some critics argue for a ban on all geoengineering field experiments and deployment[22], other observers assert that premature rejection of these technologies could be as risky for our climate as their premature use in the context of ongoing climate change[23].

According to some scholars, increasing interest in large-scale CDR and SRM approaches in the context of growing climate risks, and insufficient pledges from governments to achieve the Paris Agreement goals[16], increase the likelihood that powerful sovereign or private actors might attempt to deploy such approaches unilaterally in the coming decades[24,25] before enough is known about the risks and benefits or adequate governance is fully in place. The IPCC notes that unilateral action could potentially become a serious SRM governance issue and that existing governance mechanisms for CDR are scarce, targeted at particular options and aspects and often only at national or regional in scale[26].

What is the current status of the governance of large-scale CDR and SRM?

Governance provides the means for deciding, managing, implementing and monitoring policies and measures[4]. Governance of large-scale CDR and SRM should therefore primarily provide the means for deciding whether or not to engage with such options, and if so, how[28]. An inclusive overview of the current status of governance relating to large-scale CDR and SRM requires recognition not only of official processes and legal instruments at various levels of government, but also the contributing roles of private sector, non-governmental and civil society actors in addressing the issue[4].

International agreements and legal instruments

In terms of official processes and legal instruments at the international level, around eleven principal multilateral agreements have been identified as potentially relevant for governance of large-scale CDR or SRM[29]. Most notable among these are the UN Framework Convention on Climate Change (UNFCCC) and its Paris Agreement[30], the Convention on Biological Diversity (CBD)[31] and the London Convention[32] and London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (LC/LP)[33].

Some scholars have noted that the UNFCCC would appear to be a logical institutional home for governance of CDR[11,34,35] and suggest that the bottom-up architecture of the Paris Agreement may be well suited to a more decentralised or 'patchwork quilt' governance structure that large-scale CDR or SRM may demand[36,37]. The IPCC notes that several possible institutional arrangements have been considered for SRM governance including under the

UNFCCC and its Subsidiary Body on Scientific and Technological Advice (SBSTA)[26].

The CBD is the only international legal instrument with near universal participation[38] whose institutions have addressed geoengineering in its entirety. The IPCC notes that arrangements for SRM governance have been considered under the CBD and an international governance mechanism is in place for research and development of one form of CDR (Ocean Fertilisation)[18]. In 2010, Parties to the CBD adopted a decision on geoengineering[15] covering all technologies that may affect biodiversity, and while not expressed in legally binding language the decision is important for global governance due to the wide consensus it represents[39,40]. In 2016, Parties reasserted this decision while noting the need for more transdisciplinary research and knowledge-sharing to better understand impacts and regulatory options[41].

The LC/LP aims to protect and preserve the marine environment from all sources of pollution. Parties to the LC/LP have addressed marine geoengineering processes, and specifically ocean fertilisation, through a nonbinding decision and later as a binding (but not yet in force) amendment to the Protocol[31,42,13,43]. In 2013, Parties to the Protocol adopted a resolution to ban ocean fertilization activities other than legitimate scientific research[42], which is widely viewed as a de facto moratorium on commercial ocean fertilisation activities[26].

More broadly, specific forms of SRM could fall under other international legal instruments. For example, some forms of Stratospheric Aerosol Injection could fall under the purview of the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol, or the Convention on Long-Range Transboundary Air Pollution (CLRTAP). They may alternatively satisfy the definition of 'environmental modification' placing them within the scope of the Environmental Modification Convention (ENMOD), which prohibits hostile environmental modification 'having widespread, long-lasting or severe effects as the means of destruction, damage or injury'. Customary international law also governs transboundary risks from hazardous activities and nation-states have legally-binding duties to regulate activities that pose transboundary risks, to conduct environmental impact assessments, to notify and consult with potentially affected states, and to take reasonable measures to reduce the risks[44].

Intergovernmental organizations are also increasingly beginning to address the issue of governance through official assessment and reporting mechanisms. For example, in 2018 the IPCC special report on global warming of 1.5°C included numerous references to the issue of governing CDR and SRM[26], and in 2017 the UN Environment Emissions Gap report featured a dedicated chapter assessing CDR options including recommendations on governance[16]. In 2016, the Secretariat of the CBD published an updated technical report on geoengineering impacts and regulation related to biodiversity[38] and recent scientific assessments by the World Meteorological Organisation (WMO) under the Montreal Protocol have highlighted the potential adverse impacts some forms of SRM could have on stratospheric ozone[45,46].

Academic and other researchers

The national academies of science in the UK and USA recently published updated assessments of CDR which include various recommendations around governance[47,48]. A range of countries and private actors are funding research, and various other state and non-state actors have produced documents and proposals to influence the agenda and broker knowledge[10].

Academics and researchers are increasingly raising awareness of the need for governance[49], evident in the growing number of publications and discussions featuring in dedicated online knowledge sharing platforms[50]. Both CDR and SRM have become the subject of increasing scientific and academic scrutiny over the past decade[51], with particular interest in risks, impacts and governance considerations[52,11]. This has been facilitated by a growing number of dedicated research collaborations such as the EuTRACE[5], the GeoMIP[53], the Geoengineering Governance Research project[54], and the Forum for Climate Engineering Assessment (FCEA) Academic Working Group on international governance[55]. While some elements of research governance exist in established international agreements (e.g. CBD and LC/LP), researchers and research institutions have also been exploring other possible options

for governing geoengineering research, including: scientific self-governance[56]; high level principles[57]; codes of conduct[58]; allowed zones for experiments[59]; advisory commissions[60,61]; research commons[62] and responsible innovation[63]. The past few years has also seen an increasing number of international conferences organized by non-state actors dedicating space to the topic of geoengineering governance[64].

Non-governmental and civil society organisations

Non-governmental and civil society organisations have become increasingly active in raising awareness of geoengineering and the need for governance. Some, like the American Geophysical Union, call for more research[65], while others focus on raising awareness of governments and intergovernmental bodies such as the recent briefing to the UN Environment's Committee of Permanent Representatives[66]. Among environmental groups, a few like the Environmental Defense Fund[67] cautiously support some research, while others are critical or opposed, such as the Heinrich Böll Foundation[68], or the ETC Group[69] which has been campaigning and engaging intergovernmental processes on the topic for over a decade now[70, 71]. Coalitions of non-governmental actors continue to collaborate to provide information[72, 73] and coordinated campaigns highlighting the potential risks posed by geoengineering[74]. Others have focussed on promoting policy-dialogue, such as the Indian Council on Energy Environment and Water (CEEW)[75] which has convened conferences and briefings in the Asia-Pacific region, the Solar Radiation Management Governance Initiative (SRMGI)[76] that has facilitated workshops and provides research grants for developing countries globally, or the Carnegie Climate Geoengineering Governance Initiative (C2G2)[77] that aims to catalyse the development of geoengineering governance in the international policy arena[10].

The media

In recent years, increasing references to geoengineering have started to emerge in both specialist and mainstream media, ranging from non-fiction books[78] to fictional movies[79] and a host of articles in the popular press. On social media, an online community of 'chemtrail conspiracists' have become increasingly active[80] and the issue of geoengineering and its governance has more broadly been an increasing focus of blogs and social media postings.

What are potential next steps for governance of large-scale CDR and SRM?

Members of the international community now need to consider the policy issues that large-scale CDR and SRM raise, with a view to developing international governance[23]. An inclusive approach to such deliberation will require the engagement of various levels of government, non-governmental and civil society actors[3], ensuring sufficient alignment to establish societal legitimacy for any proposed governance framework[81] and decisions taken within it. This could be achieved through a process of learning and knowledge-sharing within and between governments and other actors (in particular those representing less developed countries, indigenous and local communities)[82,83] to increase understanding and inform future decision-making on governance. Member states' motivation to join an international governance framework might include: having a voice in diplomacy, preventing unilateral action by others, and benefits from research collaboration[26]. The United Nations' various organs, agencies and related organisations who have already begun to address climate change are likely to have a central role to play.

Addressing knowledge gaps

Substantial knowledge gaps exist around the feasibility, costs, and benefits of different

geoengineering approaches, including whether or not they would be effective at alleviating the negative impacts of climate change and how they might affect delivery of sustainable development and the Sustainable Development Goals (SDGs)[18,84]. These gaps will need to be addressed if discussions of governance are to be sufficiently well informed and a range of approaches have been identified, such as launching collaborative learning, transdisciplinary research and development activities[16,85,86,87].

Governance principles and approaches

How future governance of geoengineering might develop also requires attention. Existing research provides some initial insights into a range of different principles that could be considered, including: precautionary, transparency, minimisation of harm, intergenerational equity, international cooperation and research as a public good[5, 97]. Others have emphasised the importance of not limiting discussion to climate-related issues and ensuring transparent, accountable and participatory multilateral deliberation[88]. Various potential models for decision-making have been explored, covering the issues of consent[89], the interaction between research and deployment[21], liability[90] and other legal[44], institutional and organisational dimensions[91,92,93]. Consideration has also been given to whether a regulatory or rights-based approach to governance would be sufficient or effective[94], and at some point it may be useful to have a formal process that can examine the intersection of geoengineering and human rights[95], to effectively manage the potential effects that deployment of some technologies may have on people's right to food, health, water and life[96].

Support for sustainable development

Governance of large-scale CDR or SRM research will need to be carefully designed to ensure its support for sustainable development, to substantially reduce the risk of negative impacts[84], and include the possibility to prevent or ban use. This will require a coordinated effort across relevant intergovernmental organisations and processes, governments, research funders (public and private), and other relevant non-state actors.

Governance of large-scale Carbon Dioxide Removal (CDR)

In relation to governance of large-scale CDR, the recent UN Environment Emissions Gap report proposed a number of practical recommendations for the role that governments can play in providing funding and incentives, setting standards and giving attention to the risks and challenges presented by different options and potential policies to address them[15].

CDR might be able to be governed primarily through national and sub-national mechanisms, although there would be some need for international coordination. Any proposal for international governance will need to be discussed and aligned with national governance, and subnational and non-state actors will need to be engaged to ensure support for national governance. This will require national-level scientific assessments and national stakeholder consultations to understand perceptions[97], and a degree of voluntary reporting to international scientific bodies or specialised geoengineering forums[98].

Governance of Solar Radiation Modification (SRM)

It is unclear how the current international climate regime might govern SRM as the technologies have a less clear relationship with the objectives of the UNFCCC. Existing UN decisions (e.g. under the CBD) and other international legal instruments and mechanisms relevant to geoengineering provide important foundations for a future regime, and could be strengthened, built upon or consolidated to provide international governance with sufficient legitimacy and universality to address what the IPCC now refer to as a potentially serious governance issue[26]. As discussions on how best to handle the governance of SRM continue, the literature reviewed for this paper suggests a number of important issues for consideration which include *inter alia*:

- How to increase understanding whether or not SRM could be part of a global response to manage climate risks, and its implications;
- Whether and how to research SRM responsibly;

- To explore what governance framework(s) would allow coherent management of climate risks among the different available tools, such as emission reductions; adaptation; CDR and potentially SRM, in the overall context of sustainable development;
- To consider, in the meantime, to prevent deployment of SRM unless (1) there is enough knowledge about the risks and benefits for decision-making not only at the global level but also at regional and sub-regional levels, and (2) the world has agreed via legitimate intergovernmental processes on the governance framework needed to take decisions and govern deployment and non-deployment, as applicable;
- How to initiate the considerable research and policy work to understand how SRM functions, its impacts and how it could be governed which would be needed before the international community could be clear if SRM is even a viable option;
- How to support and finance inclusive deliberation of governance that enables effective engagement by vulnerable, indigenous and local communities;

Geoengineering methods raise understandable fears about technological hubris[28], but as the effects of global warming have become increasingly apparent, a precautionary approach whether or not to consider large-scale CDR or SRM as part of broader risk management responses to climate change is becoming a serious governance issue[26]. The ungoverned deployment of these technologies poses potentially critical environmental and geopolitical risks that now demand urgent consideration, before events overtake us.

References

1 IPCC (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Edenhofer, O., R. Pichs- Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York.

2 IPCC (2018). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)].

3 IPCC (2018). Glossary. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Matthews. R, Mustapha. B, De Coninck. H, Connors. S, van Diemen. R, Djalante. R, Kristie. E, Ellis. N, Fischlin. A, Guillén Bolaños. T, de Kleijne. K, Masson-Delmotte. V, Millar. R, Poloczanska, E. Pörtner. H-O, Reisinger. A, Rogelj. J, Seneviratne. S, Singh. C, Tschakert. P, Weyer. N, (eds.)].

4 Crutzen, P.J. (2006). Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma? Clim. Change. 77, 211–220.

5 Schäfer, S., Lawrence, M., Stelzer, H., Born, W., Low, S., Aaheim, A., ... and Vaughan, N. (2015). The European Transdisciplinary Assessment of Climate Engineering (EuTRACE): Removing Greenhouse Gases from the Atmosphere and Reflecting Sunlight away from Earth. Berlin.

6 Shepherd, J. G., Cox, P., Haigh, J., Keith, D. W., Launder, B., Mace, G., MacKerron, G., Pyle, J., Rayner, S., Redgwell, C. and Watson, A. (2009). Geoengineering the Climate: Science, Governance and Uncertainty. London: The Royal Society.

7 National Research Council (2015). Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration. Washington, DC: The National Academies Press. https://doi.org/10.17226/18805.

8 National Research Council (2015). Climate Intervention: Reflecting Sunlight to Cool Earth. Washington, DC: The National Academies Press. https://doi.org/10.17226/18988.

9 House of Commons (2010). The Regulation of Geoengineering. House of Commons Science and Technology Committee Fifth Report of Session 2009-10. HC 221. London.

10 Reynolds, J. (2018). Governing Experimental Responses: Negative Emissions Technologies and Solar Climate Engineering. [Jordan, A., Huitema, D., van Asselt, H., & Forster, J. (eds.)]. Cambridge University Press, Cambridge.

11 IPCC (2005). IPCC Special Report on Carbon Dioxide Capture and Storage [Metz, B. Davidson. O, de Coninck. H, Loos. M, and Meyer. L (eds.)] Cambridge University Press, Cambridge, UK.

12 IMO (2010). Resolution LC-LP.2 (2010) On the assessment framework for scientific research involving ocean fertilization (Adopted on 14 October 2010). The thirty-second consultative meeting on the contracting Parties to the London Convention and the 5th meeting of the contracting Parties to the London Protocol. International Maritime Organization (IMO).

13 CBD (2008). Decision IX/16: Biodiversity and Climate Change. Ninth meeting of the Conference of the Parties to the Convention on Biological Diversity, COP 9 (Nagoya, Japan: Convention on Biological Diversity (CBD)).

14 CBD (2010). Decision X/33: Biodiversity and climate change Tenth meeting of the Conference of the Parties to the Convention on Biological Diversity, COP 10 (Bonn, Germany: Convention on Biological Diversity (CBD)).

15 UNEP (2017). The Emissions Gap Report 2017. United Nations Environment Programme (UNEP), Nairobi.

16 IPCC (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Edenhofer, O., R. Pichs- Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York.

17 IPCC (2018). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)].

18 IPCC (2018). Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)].

19 Stratospheric Aerosol Injection (SAI) is the most researched method with high agreement that it could limit global warming to below 1.5oC according to: IPCC (2018) Global warming of 1.5°C. Strengthening and implementing the global response. Chapter 4. Box CB10.

20 Morrow, D. (2014). Ethical aspects of the mitigation obstruction argument against climate engineering research. Phil. Trans. R. Soc. A 372: 20140062. http://dx.doi.org/10.1098/rsta.2014.0062

21 McKinnon, C. (2018). Sleepwalking into lock-in? Avoiding wrongs to future people in the governance of solar radiation management research. Environmental Politics.

22 HOME (2018). Manifesto Against Geoengineering. Hands Off Mother Earth! Retrieved on 13.11.18 From: http://www.geoengineeringmonitor.org/2018/10/hands-off-mother-earth-manifesto-against-geoengineering/

23 Farquhar, S., Halstead, J., Cotton-Barratt, O., Schubert, S., Belfield, H., and Snyder-Beattie, A. (2017). Existential Risk: Diplomacy and governance. Global Priorities Project 2017.

24 Rabitz, Florian (2016): Going rogue? Scenarios for unilateral geoengineering. In Futures 84, pp. 98–107.DOI 10.1016/j.futures.2016.11.001.

25 Smith, J. P., Dykema, J. A., & Keith, D. W. (2018). Production of sulfates onboard an aircraft: Implications for the cost and feasibility of stratospheric solar geoengineering. Earth and Space Science, 5, 150–162.

26 de Coninck. H, A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, JC. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, T. Sugiyama. (2018). Strengthening and implementing the global response. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)].

27 IPCC (2014). Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.

28 Bodansky, D. (2013). The who, what, and wherefore of geoengineering governance. Climatic Change (2013) 121:539–

551. DOI 10.1007/s10584-013-0759-7

29 Talberg, A., Christoff, P., Thomas, S., & Karoly, D. (2017). Geoengineering governance-by-default: an earth system governance perspective. International Environmental Agreements: Politics, Law and Economics, 18(2), 229-253.

30 UNFCCC (2015). The Paris Agreement. United Nations Framework Convention on Climate Change (UNFCCC). United Nations.

31 CBD (2016) Decision XIII/14: Climate-related geoengineering. Thirteenth meeting of the Conference of the Parties to the Convention on Biological Diversity, COP 13 (Cancun, Mexico: Convention on Biological Diversity (CBD)).

32 IMO (1972). Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. International Maritime Organization (IMO).

33 IMO (2006). 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (as amended in 2006). International Maritime Organization (IMO).

34 Scott, K.N. (2013). International Law in the Anthropocene: Responding to the Geoengineering Challenge, 34 Mich. J. Int'l L. 309. Available at: http://repository.law.umich.edu/mjil/vol34/iss2/2

35 Lin, A. (2009). "Geoengineering Governance." Issues in Legal Scholarship 8(1): article 2.

36 Craik, A.N. & Burns, W.C.G. (2016). Climate Engineering under the Paris Agreement: A Legal and Policy Primer. Centre for International Governance Innovation (CIGI) Special Report.

37 Armeni C & Redgwell C, (2015). International legal and regulatory issues of climate geoengineering governance: rethinking the approach, Geoengineering Governance Working Paper Series: 021. Climate Geoengineering Governance (CGG). Oxford, UK, p. 4.

38 The CBD is signed and ratified by 196 countries apart from the USA and the Holy See. Source, accessed on 27 November 2018 from: https://www.cbd.int/information/parties.shtml

39 Williamson, P., and Bodle, R. (2016). Update on Climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework. Technical Series No.84. Secretariat of the Convention on Biological Diversity, Montreal, 158 pages.

40 The decision is referred to by some actors as a de facto moratorium on geoengineering deployment and outdoor experimentation. See for example: Biofuelwatch, Heinrich Böll Foundation and ETC Group (2017). The Big Bad Fix: the case against geoengineering. November 2017.

41 CBD (2016). Decision XIII/14: Climate-related geoengineering. Thirteenth meeting of the Conference of the Parties to the Convention on Biological Diversity, COP 13 (Cancun, Mexico: Convention on Biological Diversity (CBD)).

42 IMO (2006). 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (as amended in 2006). International Maritime Organization (IMO).

43 IMO (2013). Resolution LP 4(8). On the amendment to the London Protocol to regulate the placement of matter for ocean fertilization and other marine geoengineering activities., Resolution LC 35/15, Annex 4.

44 Reynolds, J. (2018). International Law. In M. Gerrard & T. Hester (Eds.), Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal (pp. 57-153). Cambridge: Cambridge University Press. doi:10.1017/9781316661864.003

45 WMO (2018). Executive Summary: Scientific Assessment of Ozone Depletion: 2018, World Meteorological Organization (WMO), Global Ozone Research and Monitoring Project – Report No. 58, 67 pp., Geneva, Switzerland, 2018.

46 WMO (2014). Assessment for Decision-Makers: Scientific Assessment of Ozone Depletion: 2014, 88 pp. World Meteorological Organization (WMO), Global Ozone Research and Monitoring Project—Report No. 56, Geneva, Switzerland, 2014.

47 Royal Society and Royal Academy of Engineering (2018) Greenhouse Gas Removal. Issued: September 2018 DES5563_1. ISBN: 978-1-78252-349-9

48 National Academies of Sciences, Engineering, and Medicine (2018). Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. Washington, DC: The National Academies Press. https://doi.org/10.17226/25259

49 Keith, D. (2018). Toward a Responsible Solar Geoengineering Research Program. Issues in Science and Technology, 33, 3

50 See for example: http://www.climate-engineering.eu/news.html or https://groups.google.com/forum/?hl=en#!aboutgroup/geoengineering or http://www.geoengineeringmonitor.org

51 Morrow, D. (2017). International Governance for Climate Engineering. A Survey of Reports on Climate Engineering, 2009-2015. Forum for Climate Engineering Assessment (FCEA) Working Paper Series: 001 SSRN: 2982392

52 Gupta, A. and Möller, I. (2018): De facto governance: how authoritative assessments construct climate engineering as an object of governance, Environmental Politics, DOI: 10.1080/09644016.2018.1452373

53 http://climate.envsci.rutgers.edu/GeoMIP/

54 http://geoengineering-governance-research.org

55 www.ceassessment.org/academic-working-group/

56 See for example in the context of SCoPEx: https://projects.iq.harvard.edu/keutschgroup/scopex-governance

57 Rayner S, Heyward C, Kruger T, Pidgeon N, Redgwell C and Savulescu J (2013). The Oxford Principles Clim. Change 121 499–512 Online: http://link.springer.com/10.1007/s10584-012-0675-2

58 Hubert, A-M. (2017). Code of conduct for responsible geoengineering research. Geoengineering Research Governance Project (GRGP). University of Calgary.

59 Parson, E. and Keith, D. (2013) End the Deadlock on Governance of Geoengineering Research. Science 339. no. 6125 (March 15, 2013): 279, doi:10.1126/science.1232527.

60 Winickoff, D. E. & Brown, M.B. (2013). Time for a Government Advisory Committee on Geoengineering Research. Issues in Science and Technology, Summer 2013, 79-85.

61 Parson, E. (2017). Starting a dialogue on climate engineering governance: a world commission. Policy Brief. Fixing climate governance series. No.8. August 2017. Centre of International Governance Innovation.

62 Reynolds, J.L., Contreras, J.L., and Sarnoff, J.D. (2018). Intellectual property politics for solar geoengineering. WIREs Climate Change. 2018;9:e512.

63 Stilgoe, J., Owen, R., and Macnaghten, P. (2013) Developing a framework for responsible innovation. Research Policy 42 (2013) 1568-1580.

64 See for example: "Climate Engineering Conference 2017" https://ce-conference.org or "the International Conference on negative CO2 emissions" http://negativeco2emissions2018.com

65 Landau, E. (2018), Revised AGU position statement addresses climate intervention, Eos, 99, https://doi.org/10.1029/2018EO091015. Published on 18 January 2018.

66 UNEP (2018). Committee of Permanent Representatives Briefing, 22 May 2018. Secretariat Notes. United Nations Office at Nairobi. United Nations Environment Programme. Nairobi. Retrieved on 29.08.18 from: http://wedocs.unep.org/bitstream/handle/20.500.11822/25416/Draft%20summary%20of%20briefing%20by%20the%20C2G2%20on%2022%20May%20%28rvsd%29%20final.pdf?sequence=39&isAllowed=y

67 EDF (2015). Our position on geoengineering. Environmental Defense Fund. Retrieved on 02.09.18 from: http://www.edf.org/climate/our-position-geoengineering

68 https://www.boell.de/en/geoengineering Accessed 27.11.18

69 http://www.etcgroup.org/issues/climate-geoengineering Accessed 27.11.18

70 Hands Off Mother Earth Campaign from 2010, which was supported by more than 60 organizations. Retrieved on 02.09.18: http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/pdf_file/ETCHomelaunchNR.pdf

71 ETC Group (2010) Geopiracy: The case against geoengineering. ETC Group.

72 Biofuelwatch, Heinrich Böll Foundation and ETC Group (2017). The Big Bad Fix: the case against geoengineering. November 2017.

73 For example: http://www.geoengineeringmonitor.org/ Accessed 27.11.18.

74 For example: http://www.geoengineeringmonitor.org/2018/10/hands-off-mother-earth-manifesto-against-geoengineering/ Accessed 27.11.18.

75 https://www.ceew.in/climate-geoengineering-governance Accessed 27.11.18.

76 http://www.srmgi.org Accessed 27.11.18.

77 https://www.c2g2.net Accessed 27.11.18.

78 See for example: Morton, O., (2015). The Planet Remade: How Geoengineering Could Change the World by Oliver Morton, Princeton University Press, Princeton, NJ. ISBN 9780691148250

79 See for example: https://en.wikipedia.org/wiki/Geostorm

80 Tingley, D. and Wagner, G. (2017). Solar geoengineering and the chemtrails conspiracy on social media. Palgrave Communications. Volume 3, Article number: 12 (2017).

81 Frumhoff, P.C. & Stephens, J.C. (2018). Towards legitimacy of the solar geoengineering research enterprise. Philosophical Transactions of the Royal Society A, 376.

82 Winickoff, D. E., Flegal, J. A. and Asrat, A. (2015). Engaging the Global South on climate engineering research Nat. Clim. Chang. 5 627–3.

83 Rahman, A., Artaxo, P., Asrat, A. and Parker, A. (2018). Developing countries must lead on solar geoengineering research. Comment in Nature. Vol 556.

84 Honegger, M., Derwent, H., Harrison, N., Michaelowa, A., & Schäfer, S. (2018). Carbon Removal and Solar Geoengineering: Potential implications for delivery of the Sustainable Development Goals. Carnegie Climate Geoengineering Governance Initiative, May 2018, New York, U.S.

85 C2G2 (2018). Knowledge gaps on climate-related geoengineering in relation to the Convention on Biological Diversity. Technical Briefing Paper. Carnegie Climate Geoengineering Governance Initiative (C2G2). Retrieved 18.07.18

86 Honegger, M., Derwent, H., Harrison, N., Michaelowa, A., & Schäfer, S. (2018). Carbon Removal and Solar Geoengineering: Potential implications for delivery of the Sustainable Development Goals. Carnegie Climate Geoengineering Governance Initiative, May 2018, New York, U.S.

87 Reynolds, J. (2014). The International Regulation of Climate Engineering: Lessons from Nuclear Power. Journal of Environmental Law, 26, 269-289.

88 Biofuelwatch, Heinrich Böll Foundation and ETC Group (2017). The Big Bad Fix: the case against geoengineering. November 2017.

89 Wong, P-H. (2016). Consenting to Geoengineering. Philos. Technol. (2016) 29:173–188. DOI10.1007/s13347-015-0203-1

90 Horton, J. B., Parker, A., and Keith. D.W. (2015). Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities. N.Y.U. Environmental Law Journal 22: 225-273.

91 Hester, T. and Gerrard, M. B. (2018). Going Negative: The Next Horizon in Climate Engineering Law Nat. Resour. Environ. 32 3–7

92 Nicholson, S., Jinnah, S., & Gillespie, A. (2017). Solar radiation management: a proposal for immediate polycentric governance. Climate Policy, 18(3), 322-334.

93 Lloyd, I.D. and Oppenheimer M. (2014). On the Design of an International Governance Framework for Geoengineering. Global Environmental Politics. Volume 14. Issue 2. p.45-63

94 Hester, T.D. (2018). The paradox of regulating negative emissions technologies under US environmental laws. Global Sustainability 1, e1, 1–7. https://doi.org/10.1017/sus.2018.1

95 Svoboda, T., Buck, H.J. and Suarez, P. (2018): Climate engineering and human rights, Environmental Politics, DOI: 10.1080/09644016.2018.1448575

96 Burns, W.C.G. (2016). The Paris Agreement and Climate Geoengineering Governance: The Need for a Human Rights-Based Component. Centre for International Governance Innovation (CIGI) Papers, 111.

97 Sugiyama, M., Asayama, S., Ishii, A., Kosugi, T., Moore, J.C., Lin, J., Lefale, P. F., Burns, W., Fujiwara, M., Ghosh, A., Horton, J., Kurosawa, A., Parker, A., Thompson, M., Wong, P., Xia, L. (2017). The Asia-Pacific's role in the emerging solar geoengineering debate. Climatic Change 143(1-2), 1-12. http://doi.org/10.1007/s10584-017-1994-0

98 Ghosh, A. (2017). Time for geoengineering governance. Business Standard. 25 April.