CBD

UNEP

Convention on Biological Diversity

Distr.
GENERAL

UNEP/CBD/SBSTTA/19/7
14 September 2015

ORIGINAL: ENGLISH

SUBSIDIARY BODY ON SCIENTIFIC,
TECHNICAL AND TECHNOLOGICAL ADVICE
Nineteenth meeting
Montreal, 2-5 November 2015
Item 4.2 of the provisional agenda*

# CLIMATE-RELATED GEOENGINEERING

*Note by the Executive Secretary*

## INTRODUCTION

1. This document addresses a number of issues in follow up to decision XI/20 on "Climate-related geoengineering".

2. In decision XI/20, paragraph 9, the Conference of the Parties invited Parties to report on measures undertaken in accordance with the guidance on climate-related geoengineering contained in decision X/33, paragraph 8(w). The Executive Secretary was requested to compile the information reported by Parties and to make it available through the clearing-house mechanism (decision XI/20, para. 15). Section I below summarizes such information.

3. In decision XI/20, paragraph 16(b), the Conference of the Parties requested the Executive Secretary to prepare an overview of the further views of Parties, other governments, indigenous and local communities and other stakeholders on the potential impacts of geoengineering on biodiversity, and associated social, economic and cultural impacts, taking into account gender considerations, and building on the overview of the views and experiences of indigenous and local communities contained in document UNEP/CBD/SBSTTA/16/INF/30. Section II below provides an overview of the further views received.

4. The Secretariat published, in 2012, CBD Technical Series No. 66*: Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters*.[1] This publication comprised two studies, one on the impacts of climate-related geoengineering on biodiversity, the other on the regulatory framework for climate-related geoengineering relevant to the Convention. These studies had been prepared pursuant to decision X/33, paragraph 9(l) and (m), and provided the reference basis for the consideration of this issue at the sixteenth meeting of the Subsidiary Body and for decision XI/20.

5. In decision XI/20, paragraph 16(a), the Conference of the Parties requested the Executive Secretary, subject to the availability of financial resources and at the appropriate time, to prepare, provide for peer review, and submit for consideration by a future meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, an update on the potential impacts of geoengineering techniques on

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* UNEP/CBD/SBSTTA/19/1.

[1] http://www.cbd.int/doc/publications/cbd-ts-66-en.pdf

biodiversity, and on the regulatory framework of climate-related geoengineering relevant to the Convention on Biological Diversity, drawing upon all relevant scientific reports such as the Fifth Assessment Report of the Intergovernmental Panel on Climate Change and discussions under the Environment Management Group.

6. An interim update of information on the potential impacts of climate geoengineering on biodiversity and the regulatory framework relevant to the Convention on Biological Diversity was made available in June 2014 to the Subsidiary Body at its eighteenth meeting (UNEP/CBD/SBSTTA/18/INF/5). The Synthesis Report of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change now having been published, the update requested by the Conference of the Parties has been prepared for the consideration of the Subsidiary Body at its nineteenth meeting. It was finalized following review by Parties and experts during August 2015. The "Update on Climate Geoengineering in relation to the Convention on Biological Diversity" is presented in document UNEP/CBD/SBSTTA/19/INF/2, and a summary is provided in section III of the present note.

7. Section IV presents the suggested recommendations.

## I. INFORMATION ON MEASURES UNDERTAKEN IN ACCORDANCE WITH DECISION X/33, SUBPARAGRAPH 8(W)

8. In decision XI/20, the Conference of the Parties invited Parties to report on measures undertaken in accordance with paragraph 8(w) of decision X/33, which contains the following guidance:

> "Ensure, in line and consistent with decision IX/16 C, on ocean fertilization and biodiversity and climate change, in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment."

9. Accordingly, the Executive Secretary sent a first notification (2013-102)[2] on 12 November 2013, and a second notification (2015-015)[3] on 12 February 2015, inviting Parties to submit information on any measures they have undertaken in accordance with decision X/33, paragraph 8(w). The Secretariat provided a first summary of the information submitted in 2013 by three Parties (Estonia, United Kingdom of Great Britain and Northern Ireland and France) for the consideration of the Subsidiary Body at its eighteenth meeting (see UNEP/CBD/SBSTTA/18/13). In response to the second notification issued in 2015, four Parties submitted information (United Kingdom of Great Britain and Northern Ireland, France, Canada and the Plurinational State of Bolivia). The compilation of submissions is available at: http://www.cbd.int/climate/geoengineering/.

10. In response to the fist notification, Estonia informed the Secretariat that, at the time of the submission, there were no large-scale scientific studies undertaken in Estonia in accordance with paragraph 8(w) of decision X/33. Any geoengineering project which could potentially have significant environmental impacts would need to follow the rules set out in Estonia's National Environmental Impact Assessment Act.

11. In its first submission, the United Kingdom of Great Britain and Northern Ireland (UK) provided information on (a) the regulatory framework for geoengineering proposals in the UK; (b) actions taken by

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[2] https://www.cbd.int/doc/notifications/2013/ntf-2013-102-geoeng-en.pdf.

[3] https://www.cbd.int/doc/notifications/2015/ntf-2015-016-cc-geoeng-en.pdf.

the UK Government relevant to geoengineering; and (c) supplementary information provided by Research Councils UK, including a list of recent and current UK research projects that are contributing to the understanding of climate-related geoengineering.[4] In response to the second notification, the UK confirmed that the paper submitted in 2013 continues to represent their position.

12. In response to the first notification, France submitted a note prepared by its biodiversity research foundation (*Fondation pour la Recherche sur la Biodiversité)*. According to the scientific expert group convened by the foundation, as of January 2014, no small-scale scientific research studies had taken place in France. With regard to ocean fertilization (mainly by iron), at the time of the first submission, no projects with the objective of geoengineering were underway in France. However, for about ten years, research had been conducted in France to understand the mechanisms linking iron fertilization and the $CO_2$ biological pump in the ocean. These research studies used natural analogues of fertilization, i.e. areas that are naturally fertilized by iron (e.g. the KEOPs project). Other research included a report on the issues and methods for environmental engineering, and modelling studies.

13. In response to the second notification, France re-submitted the note prepared by the *Fondation pour la Recherche sur la Biodiversité*, and, in addition, shared information regarding a report prepared by a Consortium of scientists on considerations of geoengineering issues and techniques titled “Réflexion systémique sur les enjeux et méthodes de la géo-ingénierie de l’environnement”.[5] The report examines different geoengineering techniques and discusses related issues such as societal aspects.

14. Canada, in its submission, mentioned that it has supported compatible decisions when participating in relevant international fora, such as the amendment of the London Protocol to further regulate ocean fertilization by creating a permitting regime for legitimate scientific research, and to create a mechanism for regulating other types of marine geoengineering in the future. Canada also reported that it is collaborating in the Geoengineering Model Intercomparison Project (GeoMIP) of the World Climate Research Programme.

15. The Plurinational State of Bolivia, in its submission, reaffirmed its position expressed when they issued a reservation to their acceptance of the final text of the Summary for Policymakers of Working Group II on Mitigation of Climate Change of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), emphasizing that technologies proposed by IPCC to promote mitigation actions are primarily framed through the use of geoengineering based on Carbon Dioxide Removal (CDR) technologies, particularly with the use of biotechnologies and genetically modified crops, and stating that these technologies violate the rights of Mother Earth, and particularly its right of adapting naturally to climate change, and have an important impact on the livelihoods and fundamental rights of local and indigenous peoples. Bolivia considers that geoengineering technologies should not be used, and provided references to studies that demonstrate the potential impacts of geoengineering.[6]

[4] Further information is available in UNEP/CBD/SBSTTA/18/13.

[5] “Réflexion systémique sur les enjeux et méthodes de la géo-ingénierie de l’environnement”, available at http://arp-reagir.fr. This report was reviewed in preparation of the Update.

[6] Tilmes et al (2013); Ferraro et al (2014). These papers were reviewed in the 2015 Update. Full references are provided therein.

## II. FURTHER VIEWS OF PARTIES, OTHER GOVERNMENTS, INDIGENOUS AND LOCAL COMMUNITIES AND OTHER STAKEHOLDERS ON THE POTENTIAL IMPACTS OF GEOENGINEERING ON BIODIVERSITY, AND ASSOCIATED SOCIAL, ECONOMIC AND CULTURAL IMPACTS

16. In decision XI/20, paragraph 16(b), the Conference of the Parties requested the Executive Secretary to prepare an overview of the further views of Parties, other governments, indigenous and local communities and other stakeholders on the potential impacts of geoengineering on biodiversity, and associated social, economic and cultural impacts, taking into account gender considerations, and building on the overview of the views and experiences of indigenous and local communities contained in document UNEP/CBD/SBSTTA/16/INF/30.

17. Pursuant to this request, the Executive Secretary, in notification (2015-015)[3] invited Parties to provide further views on the potential impacts of geoengineering on biodiversity and associated social, economic and cultural impacts.

18. In response to this notification, Canada acknowledged the information on potential impacts of geoengineering provided in the Synthesis Report of the Fifth Assessment Report of IPCC, such as the assessment of the side effects and environmental impacts of geoengineering techniques, including carbon dioxide removal (CDR) and solar radiation management (SRM).

19. In its submission Canada also referred to three iron fertilization events which took place in 2012 near Haida Gwaii, British Columbia. The submission provided a summary of findings from studies on the effects of these events. Canada stated that the full impact of these iron fertilization events to carbon cycling and ecosystem responses, particularly at higher trophic levels, has yet to be understood. It also specified that these iron fertilization events were not authorized by the Government of Canada and are under current investigation.

20. The Plurinational State of Bolivia, in its submission, stated that indigenous peoples and local communities that live in the Amazon region, the Andean region and high altitude ecosystems, are directly affected by the adverse impacts of climate change on livelihoods, access to natural resources, and changes to socio-economic and cultural structures, increasing the gap between the rich and the poor.

21. According to the Plurinational State of Bolivia, technology must be used to improve life and provide well-being for development that is in balance and harmony with Mother Earth.

## III. SUMMARY OF THE UPDATE ON CLIMATE GEOENGINEERING IN RELATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY

*Introduction*

22. In 2012, the Secretariat of the Convention on Biological Diversity published, Technical Series No. 66: *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters* ("the 2012 Studies") comprising two studies[7]: one on the impacts of climate-related geoengineering on biodiversity, the other on the regulatory framework for climate-related geoengineering relevant to the Convention. These studies were prepared pursuant to decision X/33 paragraph 9(l) and (m), and provided the reference basis for the consideration of this issue at the sixteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice and the eleventh meeting of the Conference of the Parties.

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[7] Secretariat of the Convention on Biological Diversity (2012) *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters*, Montreal, Technical Series No. 66, 152 pages. http://www.cbd.int/doc/publications/cbd-ts-66-en.pdf, comprising Part I: Williamson, P., Watson, R.T., Mace, G., Artaxo, P., Bodle, R., Galaz, V., Parker, A., Santillo, D., Vivian, C.,Cooper, D., Webbe, J., Cung, A. and E. Woods (2012). I*mpacts of Climate-Related Geoengineering on Biological Diversity*, and Part II: Bodle, R., with Homan, G., Schiele, S., and E. Tedsen (2012). *The Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity*.

23. The main remit of the 2015 Update is to provide an update on the potential impacts of geoengineering techniques on biodiversity together with an account of regulatory developments.[8] An interim update was provided to the Subsidiary Body at its eighteenth meeting in 2014. There have been very many scientific papers and reports relevant to climate geoengineering during the past three years, with approximately 350 such publications cited in the 2015 Update. Geoengineering has also been addressed by all three Working Groups of the Intergovernmental Panel on Climate Change in its Fifth Assessment Report, and in a number of other major reports. The 2015 Update is provided in document UNEP/CBD/SBSTTA/19/INF/2. The present note provides the key messages of the 2015 Update. These key messages complement those in the 2012 Studies (Annex) which remain valid.

24. As in the original report, **climate-related geoengineering is defined as a deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts**. This definition is used for the purposes of the 2015 Update without prejudice to any definition that may subsequently be agreed under the Convention. "Climate engineering" and "climate intervention" may be considered as equivalent to "climate-related geoengineering", hereafter geoengineering. Generally, climate-related geoengineering is divided into two main groups at the technique level: (i) techniques involving greenhouse gas removal (GGR) (also known as "negative emission techniques"; most existing and proposed techniques fall under the term "carbon dioxide removal" (CDR)); and (ii) techniques known as sunlight reflection methods (SRM; alternatively "solar radiation management" or "albedo management"). In addition there are other proposed techniques, that could directly increase heat loss, or redistribute energy within the Earth system. Key features of the definition are that the interventions are deliberate, and are on a scale large enough to have a significant counter-acting effect to the warming effect of greenhouse gases. They are thus distinct from actions to reduce emissions. However, some of the techniques involving greenhouse gas removal, such as afforestation, reforestation, techniques for managing soils to increase carbon sequestration, and the use of bioenergy combined with carbon capture and storage, are also considered climate mitigation techniques. Not all of the latter techniques are considered by all stakeholders to be geoengineering. In any case, interventions (both GGR and SRM) that are carried out at a small scale (eg: local tree planning projects; roof whitening) are not normally considered as geoengineering. In line with decision X/33, the definition also excludes carbon capture at source from fossil fuels (CCS; i.e, preventing the release of $CO_2$ into the atmosphere), while recognizing that the carbon storage components of that process may also be shared by other techniques that are considered as geoengineering.

25. **Assessment of the impacts of geoengineering on biodiversity is not straightforward and is subject to many uncertainties.** Relatively little research has *directly* addressed the issue of 'impacts on biodiversity', nor even broader environmental implications: instead effort by natural scientists has mostly focussed on climatic (physico-chemical) issues or impacts on agricultural systems, while social scientists have addressed governance, framing and ethical considerations. This 2015 Update, as the original 2012 Studies, considers the impacts of geoengineering on the drivers of biodiversity loss, including the potential decrease in the climate change driver from effective geoengineering techniques, changes in other drivers, including land-use change, that are inevitably associated with some geoengineering approaches, as well as the other positive and negative side effects of specific techniques. Consequences for biodiversity are therefore mostly discussed in terms of climatic effectiveness, land-use change or other indirect impacts; e.g. fertilizer application or water extraction. It is important to note that both decreased and increased productivity tend to be undesirable from a natural ecosystem perspective, although the latter is likely to be beneficial in agricultural systems.

*Climate Change*

26. **Climate change is already impacting biodiversity and further impacts are inevitable**. It may still be possible that deep and very rapid decarbonization by all countries might allow climate change to be kept within a 2°C limit by emission reduction alone. However any such window of opportunity is

[8] UNEP/CBD/SBSTTA/18/INF/5

rapidly closing. Even so, climate change associated with 2°C warming will have serious impacts on biodiversity. Emissions under current trajectories, broadly consistent with RCP 8.0 (the highest of the four main scenarios used in the IPPC AR5) would lead to an extremely large loss of biodiversity. Current commitments made by Parties to UNFCC would significantly reduce climate change and its impacts (probably to a pathway between RCP 6 and RCP 4.5) but are insufficient to keep warming within 2°C. Geoengineering techniques, if viable and effective, would be expected to reduce climate change impacts on biodiversity. However some techniques would lead to biodiversity loss through other drivers such as land-use change.

*Carbon dioxide removal (Greenhouse gas removal)*

27. **Scenarios of future climate change to 2100 that are likely to keep global average temperature increases within a limit of 2 degrees Celsius above pre-industrial levels mostly rely on technologies for carbon dioxide removal (CDR) as well as emission reductions, with pathways that feature net negative emissions in the second half of the century**. **However, the potential to deploy CDR at this scale is highly uncertain**. The deployment of CDR envisaged by scenarios reported in the Fifth Assessment Report of IPCC in the period 2050-2100 would allow additional anthropogenic greenhouse-gas emissions in the period up to 2050, extending the period of fossil fuel use and potentially reducing the cost of their phase-out. For RCP 2.6, approximately 90 per cent of the pathways considered in IPCC AR5 assume the deployment of CDR technologies. Bioenergy with carbon capture and storage (BECCS) and/or afforestation/reforestation (AR) are seen as the most economically viable ways to provide such net negative emissions. The land and water use requirements of BECCS and AR are limiting factors, but those requirements, and their implications, are not well factored into existing models. For BECCS, $CO_2$ storage capacity may also be limiting.

28. **The removal of a given quantity of a greenhouse gas would not fully compensate for an earlier "overshoot" of emissions.** The occurrence of an overshoot in most RCP 2.6 scenarios allows for current emissions to be offset by future "negative emissions". The assumption is made that CDR will be achievable at the scale required, without such actions themselves having significant undesirable consequences; this assumption seems unlikely to be valid. In particular, not all the climatic and environmental consequences of the overshoot will be directly cancelled by future $CO_2$ removal. The net effect of adding and subsequently subtracting a given quantity of $CO_2$ only equals zero when there is no significant time difference between the addition and subtraction processes; a delay of approximately 50 years would lead to significant and potentially irreversible consequences for biodiversity and the Earth system. For those reasons, the evaluation of the potential role of CDR techniques should focus on their effectiveness in helping to reduce net emissions to zero on a shorter timescale than envisaged in most current scenarios, complementing stringent emission reductions.

29. **The large-scale deployment of bioenergy with carbon capture and storage (BECCS) seems likely to have significant negative impacts on biodiversity through land use change.** If BECCS were deployed to a scale assumed in most RCP 2.6 scenarios, substantial areas of land (several hundred million hectares), water (potentially doubling agricultural water demand) and fertilizer would be needed to sustain bioenergy crops. Limiting irrigation to reduce water use, or not replacing nutrients, would increase land requirements. Even under optimistic scenarios, less than half of the requirements for negative emissions could likely be met from abandoned agricultural land. Land-use change envisaged in the central RCP 2.6 scenario would lead to large losses of terrestrial biodiversity.

30. **Ecosystem restoration including reforestation and appropriate afforestation can contribute to removing carbon dioxide and provide substantive biodiversity co-benefits. However, these activities on their own would be insufficient to remove carbon at the scale required in most current scenarios**. Avoiding deforestation, and the loss of other high-carbon natural vegetation, is more efficient than restoration or afforestation in contributing to climate mitigation and has greater biodiversity co-benefits. Afforestation of ecosystems currently under non-forest native vegetation would result in the

loss of the biodiversity unique to such habitats, and from an ecological perspective, should be avoided.[9] Furthermore, the greenhouse effects of $N_2O$ arising from nitrogen fertilizers may outweigh the $CO_2$ gains; afforestation of boreal areas and desert areas would increase global warming though albedo effects; and future climate change may jeopardize forest carbon sinks, through increased frequency of fire, pests and diseases and extreme weather events.

31. **Biochar may potentially contribute to carbon dioxide removal under certain circumstances, and the technique applied to agricultural soils may offer productivity co-benefits**. The application of biochar (charcoal) to soils may have positive or negative impacts on soil biodiversity and productivity, but there is greater evidence of positive impacts, especially in acidic soils. In addition, biochar application to soils may also decrease soil carbon emissions. A quantitative understanding of the factors affecting the permanence of biochar carbon sequestration is being developed. However, until the use of coal and other high-emission fossil fuels are phased out, the alternative use of charcoal as fuel may have greater potential in climate mitigation. Assessments of the climatic benefits, co-benefits and costs of different biochar processes and products are needed to fully evaluate the potential of this technique. Current scenarios envisage the production of biochar from crop residues and food wastes. Nevertheless, deployment of this technique on a large scale would have significant direct and indirect impacts on the use of land, water and fertilizers to generate the biomass required.

32. **The viability of alternative negative emission techniques such as direct air capture (DAC), enhanced weathering and ocean fertilization remains unproven.** There has been significant research work since the 2012 Studies, yet conclusions remain broadly the same. Likely costs and energy requirements of DAC for $CO_2$ are still very high, albeit considerably lower than those reported in the 2012 Studies. Since there may be further potential for cost reductions, additional research on DAC techniques for $CO_2$, as well as methane, warrants attention. The potential contribution of enhanced weathering, on land or in the ocean, to negative emissions is unclear but logistical factors seem likely to limit deployment at large scales. Local marine application might be effective in slowing or reducing ocean acidification, with consequent benefits for marine biodiversity, though there might also be negative effects; e.g. from sedimentation. Enhancing ocean productivity, by stimulating phytoplankton growth in the open ocean and through nutrient addition ("ocean fertilization") or modification of upwelling, is only likely to sequester relatively modest amounts of $CO_2$, and the environmental risks and uncertainties associated with large-scale deployment remain high.

33. **Carbon dioxide (or other greenhouse gases) captured from the atmosphere must be stored in some form. Options include vegetation, soils, charcoal, or carbon dioxide in geological formations**. Vegetation, soils and charcoal demonstrate varying levels of (im)permanence. Technical considerations relating to safe carbon storage in geological formations, mostly expected to be beneath the seafloor, have recently been reviewed. The main effects of marine leakage would be local ocean acidification with experimental studies indicating that (at least for slow release rates) environmental impacts would be relatively localized. The extensive literature on ocean acidification, including the biodiversity changes observed at natural $CO_2$ vents, is relevant here. However, relatively few experimental studies on the impacts of high $CO_2$ on marine organisms cover the full range of values that might occur under leakage conditions. Other forms of storage in the ocean are considered to have unacceptable risks, and are not allowed under the London Convention/London Protocol.

*Sunlight reflection methods/Solar radiation management*

34. **Recent studies and assessments have confirmed that SRM techniques, in theory, could slow, stop or reverse global temperature increases. Thus, if effective, they may reduce the impacts on biodiversity from warming, but there are high levels of uncertainty about the impacts of SRM techniques, which could present significant new risks to biodiversity.** Modelling work consistently

[9] The term "afforestation" under UNFCC refers to the forestation of land that has not carried trees for at least 50 years. Thus, the term may include reforestation of some previously forested lands as well as afforestation of ecosystems under non-forest native vegetation.

demonstrates that reduction in average global temperature (or prevention of further increase) and, to some extent, associated precipitation changes, would be possible, but would not fully restore future climatic conditions to their present day status. The regional distribution of temperature and precipitation effects are also different for different SRM techniques; these have been modelled, but many uncertainties remain. Even if, on average, the resulting disruptions to regional climates under SRM are less than those under climate change in the absence of SRM, this cannot be known with certainty: the possibility that some regions would benefit while others might suffer even greater losses, would have complex implications for governance. The implications for biodiversity have not been examined in most models. However, if SRM were to be started, but subsequently halted abruptly, termination effects (involving very rapid climate changes) would likely lead to serious losses of biodiversity. The use of CDR in addition to 'moderate' SRM could reduce such risks, and there is increasing emphasis in the scientific literature on the potential complementarity of the two approaches.

35. **Models suggest SRM could slow the loss of Arctic sea ice. However, preventing the loss of Arctic sea ice through SRM is unlikely to be achievable without unacceptable climatic impacts elsewhere.** Models suggest that even if SRM were globally deployed at a scale that returned average global temperatures to pre-industrial levels, Arctic sea ice loss would continue, albeit at a slower rate. Further loss of Arctic sea ice might be prevented by locally-strong SRM (using asymmetric application of stratospheric aerosols) but this would be associated with extremely negative impacts elsewhere due to major shifts in atmospheric and oceanic circulations. Cirrus cloud thinning may, in theory, be able to stabilize Arctic sea ice, but many uncertainties remain regarding that technique.

36. **SRM may benefit coral reefs by decreasing temperature-induced bleaching, but, under high $CO_2$ conditions, it may also increase, indirectly, the impacts of ocean acidification**. Notwithstanding uncertainties over regional distribution, lowered average global temperatures under SRM would be likely to reduce the future incidence of bleaching of warm-water corals (compared to RCP 4.5 or RCP 6.0 conditions). The interactions between ocean acidification, temperature and impacts on corals (and other marine organisms) are complex, and much will depend on the scale of additional measures taken to reduce the increase in atmospheric $CO_2$. If warming is prevented by SRM, there will be less additional $CO_2$ emissions from biogeochemical feedbacks; however, relative cooling would reduce carbonate saturation state, that may reduce calcification or even dissolve existing structures (for cold-water corals) if $CO_2$ emissions are not constrained.

37. **The use of sulphur aerosols for SRM would be associated with a risk of stratospheric ozone loss; there would also be more generic side effects involved in stratospheric aerosol injection (SAI)**. While ozone depletion effects may be avoidable if alternative aerosols are used, their suitability and safety have yet to be demonstrated. All SAI techniques would, if effective, change the quality and quantity of light reaching the Earth's surface; the net effects on productivity are expected to be small, but there could be impacts on biodiversity (community structure and composition).

38. **The climatic effectiveness of marine cloud brightening depends on assumptions made regarding microphysics and cloud behaviour.** Many associated issues are still highly uncertain. The potential for regional-scale applications has been identified; their environmental implications, that include salt damage to terrestrial vegetation, have not been investigated in any detail.

39. **Large scale changes in land and ocean surface albedo do not seem to be viable or cost-effective.** It is very unlikely that crop albedo can be altered at a climatically-significant scale. Changing the albedo of grassland or desert over sufficiently large areas would be very resource-demanding, damaging to biodiversity and ecosystems, and likely cause regional-scale perturbations in temperature and precipitation. Changes in ocean albedo (through long-lasting foams) could, in theory, be climatically effective, but would be also accompanied by many biogeochemical and environmental changes, likely to have unacceptably large ecological and socioeconomic impacts.

*Techniques aimed at increasing heat loss*

40. **Cirrus cloud thinning may have potential to counteract climate change, but the feasibility and potential impacts of the technique have received little attention**. This technique would allow

more heat (long-wave radiation) to leave the Earth, in contrast to SRM (which aims to reflect incoming short-wave energy).

*Socio-economic and cultural considerations*

41. **Recent social science literature has focussed on framing, governance and ethical issues relating to atmospheric SRM.** Research has also covered international relations, national and international law, and economics, with most papers by US and European authors. While the socioeconomics of large-scale, land-based $CO_2$ removal techniques has, to some degree, been covered by discussion on biofuels and their implications for food security, there are major gaps regarding the commercial viability of CDR techniques, such as BECCS, their associated institutional frameworks relating to carbon trading or tax incentives, and evaluations of environmental impacts (in context of ecosystem services) and implications for indigenous peoples and local communities. For SRM, many different frames have been considered, with those based on climate emergencies' or 'tipping points' attracting particular interest and criticism. There is an increasing, trend towards multidisciplinary and transdisciplinary programmes on climate geoengineering, and these are now beginning to deliver more integrated analyses, with a collaborative role for social scientists.

42. **Where surveyed, the public acceptability of geoengineering is generally low**, particularly for SRM. Nevertheless, studies in a range of countries have found broad approval for research into both CDR and SRM techniques, provided that the safety of such research can be demonstrated.

*Regulatory framework*

43. **An amendment to the London Protocol to regulate the placement of matter for ocean fertilization and other marine geoengineering activities has been adopted by the Contracting Parties to the London Protocol**. This relates to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 administered by the International Maritime Organization. The amendment, adopted in 2013, is structured to allow other marine geoengineering activities to be considered and listed in a new annex in the future if they fall within the scope of the Protocol and have the potential to harm the marine environment. The amendment will enter into force following ratification by two thirds of the Contracting Parties to the London Protocol. This amendment, once entered into force, will strengthen the regulatory framework for ocean fertilization activities and provide a framework for the further regulation of other marine geoengineering activities. The Conference of the Parties to the Convention on Biological Diversity, in decision XII/20, took note of Resolution LP.4(8) and invited parties to the London Protocol to ratify this amendment and other Governments to apply appropriate measures in line with this amendment, as appropriate.

44. **The 2007 amendment to the OSPAR Convention which allows storage of carbon dioxide in geological formations under the seabed of the North-East Atlantic entered into force in July 2011** and is currently in force for 11 of the 16 OSPAR parties.

45. As noted in the original report**, the need for science-based global, transparent and effective control and regulatory mechanisms may be most relevant for those geoengineering techniques that have a potential to cause significant adverse transboundary effects, and those deployed in areas beyond national jurisdiction and in the atmosphere**. These would comprise a subset of the techniques included in the broad definition of climate-related geoengineering (para 24, above). Many ocean-based potential geoengineering approaches are already covered under the LC/LP as note above. However, the large-scale BECCS and afforestation proposed in many IPCC AR5 scenarios may raise new regulatory issues at the international level regarding the associated scale of land use and land-use change. The potential international governance implications of such large-scale BECCS have so far not been specifically addressed by the international regulatory framework or literature.

46. **The lack of regulatory mechanisms for SRM remains a major gap.** With regard to **SRM**, IPCC AR5 notes that “the governance implications...are particularly challenging”, in particular in respect of the political implications of potential unilateral action. The spatial and temporal redistribution of risks raises

additional issues of intra-generational and inter-generational justice[10], which has implications for the design of international regulatory and control mechanisms. The ethical and political questions raised by SRM would require public engagement and international cooperation in order to be addressed adequately. Other approaches that involve modifications to the atmospheric environment include cirrus cloud thinning are also not covered.

47. **A recurring question is how research activities (as opposed to potential deployment) should and could be addressed by a regulatory framework**. However, once the modelling and laboratory stage has been left behind, the distinction between research and development could become difficult to draw for regulatory purposes. It has been argued that governance can have an enabling function for "safe and useful" research; the London Protocol's concept of "legitimate scientific research" underlying the 2013 amendment can be seen in this context.

48. **These developments have not changed the validity of the key messages from Part II of the 2012 Studies**, including that "the current regulatory mechanisms that could apply to climate-related geoengineering relevant to the Convention do not constitute a framework for geoengineering as a whole that meets the criteria of being science-based, global, transparent and effective" and that "with the possible exceptions of ocean fertilization experiments and $CO_2$ storage in geological formations, the existing legal and regulatory framework is currently not commensurate with the potential scale and scope of climate related geoengineering, including transboundary effects."

*Conclusions*

49. **Biodiversity is affected by a number of drivers of change that will themselves be impacted by proposed CDR and SRM geoengineering techniques.** If effective, geoengineering would reduce the impacts of climate change on biodiversity at the global level. However, in the case of SRM under conditions of high $CO_2$ this would not necessarily be the case at local levels, due to an inherently unpredictable distribution of temperature and precipitation effects. On the other hand, the benefits for biodiversity of reducing climate change impacts through large-scale biomass-based $CO_2$ removal seem likely to be offset, at least in part, and possibly outweighed, by land-use change. Changes in ocean productivity through large-scale fertilization would necessarily involve major changes to marine ecosystems, with associated risks to biodiversity. In general, technique-specific side effects that may be detrimental for biodiversity are not well understood.

50. **Assessment of the direct and indirect impacts (each of which may be positive or negative) of climate geoengineering is not straightforward.** Such considerations necessarily involve uncertainties regarding technical feasibility and effectiveness; scale dependencies; and complex comparisons with non-geoengineered conditions as well as value judgements and ethical considerations. Technique-specific considerations important for the evaluation of climate geoengineering techniques include effectiveness, safety and risks; co-benefits; readiness; governance and ethics; and cost and affordability. Many of these factors cannot yet be reliably quantified, and it is important that 'cost' includes both market and non-market values. Further research, with appropriate safeguards, could help to reduce some of these knowledge gaps and uncertainties.

## IV. SUGGESTED RECOMMENDATION

The Subsidiary Body on Scientific, Technical and Technological Advice may wish to:

(a) *Take note* of the updated report on climate-related geoengineering in relation to the Convention on Biological Diversity (UNEP/CBD/SBSTTA/19/INF/2) and its key messages (UNEP/CBD/SBSTTA/19/7);

(b) *Recommend* that the Conference of the Parties *take note* that very few Parties provided information on measures they have undertaken in accordance with decision X/33, paragraph 8(w), and *call upon* other Parties, where relevant, to provide such information.

[10] IPCC AR5 Synthesis report p. 89; WGIII p. 488.

*Annex*

The following key messages were identified in Technical Series No. 66 (CBD, 2012) (The parts highlighted in bold in the original studies are reproduced here; the full text is available in the full studies).

***Key messages from Technical Series No. 66 Part I:*** *Impacts of Climate-Related Geoengineering on Biological Diversity (Williamson et al, 2012)*

1. Biodiversity, ecosystems and their services are critical to human well-being. Protection of biodiversity and ecosystems requires that drivers of biodiversity loss are reduced.

*Proposed climate-related geoengineering techniques*

2. In this report, climate-related geoengineering is defined as a deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts.

3. Sunlight reflection methods (SRM), also known as solar radiation management, aim to counteract warming and associated climatic changes by reducing the incidence and subsequent absorption of short-wave solar radiation, reflecting a small proportion of it back into space.

4. Carbon dioxide removal (CDR) techniques aim to remove CO2, a major greenhouse gas, from the atmosphere

5. There is no single geoengineering approach that currently meets all three basic criteria for effectiveness, safety and affordability. Different techniques are at different stages of development, mostly theoretical, and many are of doubtful effectiveness.

*Climate change and ocean acidification, and their impacts on biodiversity*

6. The continued increase in CO2 and other atmospheric greenhouse gases not only has profound implications for global and regional average temperatures, but also for precipitation, soil moisture, ice-sheet dynamics, sea-level rise, ocean acidification and the frequency and magnitude of extreme events such as floods, droughts and wildfires.

7. Since 2000, the rate of increase in anthropogenic CO2 emissions has accelerated, averaging ~3.1% per year. Emissions of other greenhouse gases are also increasing. As a result, it will be extremely challenging to limit global warming to the proposed target of 2°C.

8. Even with strong climate mitigation policies, further human-driven climate change is inevitable due to lagged responses in the Earth climate system.

9. Human-driven climate change poses an increasingly severe range of threats to biodiversity and ecosystem services, greatly increasing the risk of species extinctions and local losses.

10. The terrestrial impacts of projected climate change are likely to be greatest for montane and polar habitats, for coastal areas affected by sea-level change, and wherever there are major changes in freshwater availability.

11. Marine species and ecosystems are increasingly subject to ocean acidification as well as changes in temperature.

12. The biosphere plays a key role in climate processes, especially as part of the carbon and water cycles.

*Potential impacts on biodiversity of SRM geoengineering*

13. SRM, if effective in abating the magnitude of warming, would reduce several of the climate-change related impacts on biodiversity. Such techniques are also likely to have other, unintended impacts on biodiversity.

14. Model-based analyses and evidence from volcanic eruptions indicate that uniform dimming of sunlight by 1–2% through an unspecified atmospheric SRM measure could, for most areas of the planet, reduce future temperature changes projected under unmitigated greenhouse gas emissions.

15. SRM would introduce a new dynamic between the heating effects of greenhouse gases and the cooling due to sunlight reduction.

16. The amount of anthropogenic CO2 in the atmosphere is unaffected by SRM. Thus SRM would have little effect on ocean acidification and its associated impacts on marine biodiversity, nor the impacts (positive or negative) of elevated atmospheric CO2 on terrestrial ecosystems.

17. Rapid termination of SRM, that had been deployed for some time and masking a high degree of warming due to continued greenhouse-gas emissions, would almost certainly have large negative impacts on biodiversity and ecosystem services.

18. Stratospheric aerosol injection, using sulphate particles, would affect the overall quantity and quality of light reaching the biosphere; have relatively minor effects on atmospheric acidity; and could also contribute to stratospheric ozone depletion.

19. Cloud brightening is a more localised SRM proposal, with its application likely to be limited to specific ocean areas. The predictability of its climatic impacts is currently uncertain.

20. Surface albedo changes would need to be deployed over very large land areas (sub-continental scale) or over much of the global ocean to have substantive effects on the global climate, with consequent impacts on ecosystems. Strong localized cooling could have a disruptive effect on regional weather patterns.

*Potential impacts on biodiversity of CDR geoengineering techniques*

21. Carbon dioxide removal techniques, if effective and feasible, would be expected to reduce the negative impacts on biodiversity of climate change and, in most cases, of ocean acidification.

22. Individual CDR techniques may have significant unintended impacts on terrestrial, and/or ocean ecosystems, depending on the nature, scale and location of carbon capture and storage.

23. Ocean fertilization involves increased biological primary production with associated changes in phytoplankton community structure and species diversity, and implications for the wider food web.

24. Enhanced weathering would involve large-scale mining and transport of carbonate and silicate rocks, and the spreading of solid or liquid materials on land or sea. The scale of impacts (that may be positive as well as negative) on terrestrial and coastal ecosystems will depend on the method and scale of implementation.

25. The impacts on biodiversity of ecosystem carbon storage through afforestation, reforestation, or the enhancement of soil and wetland carbon depend on the method and scale of implementation.

26. Production of biomass for carbon sequestration on a scale large enough to be climatically significant is likely to either compete for land with food and other crops or involve large-scale land-use change, with impacts on biodiversity as well as greenhouse-gas emissions that may partially offset (or even exceed) the carbon sequestered as biomass.

27. The impacts of long-term storage of biochar (charcoal) in different soil types and under different environmental conditions are not well understood.

28. Ocean storage of terrestrial biomass (e.g., crop residues) is expected to have a negative impact on biodiversity.

29. Chemical capture of CO2 from ambient air would require a large amount of energy. Some proposed processes may also have high demand for freshwater, and potential risk of chemical pollution from sorbent manufacture; otherwise they would have relatively small direct impacts on biodiversity.

30. Ocean $CO_2$ storage will necessarily alter the local chemical environment, with a high likelihood of biological effects.

31. Leakage from $CO_2$ stored in sub-seafloor geological reservoirs, though considered unlikely if sites are well selected, would have biodiversity implications for benthic fauna on a local scale.

*Social, economic, cultural and ethical considerations of climate-related geoengineering*

32. The consideration of geoengineering as a potential option raises many socio-economic, cultural and ethical issues, regardless of the specific geoengineering approach.

33. Humanity is now the major force altering the planetary environment.

34. The 'moral hazard' of geoengineering is that it is perceived as a technological fall-back, possibly reducing effort on mitigation.

35. In addition to limiting the undesirable impacts of climate change, the large-scale application of geoengineering techniques is near-certain to involve unintended side effects and increase socio-political tensions.

36. An additional issue is the possibility of technological, political and social "lock in".

37. Geoengineering raises a number of questions regarding the distribution of resources and impacts within and among societies and across time.

38. In cases in which geoengineering experimentation or interventions might have transboundary effects or impacts on areas beyond national jurisdiction, geopolitical tensions could arise.

*Synthesis*

39. The deployment of geoengineering techniques, if feasible and effective, could reduce the magnitude of climate change and its impacts on biodiversity. At the same time, most geoengineering techniques are likely to have unintended impacts on biodiversity, particularly when deployed at a climatically-significant scale, together with significant risks and uncertainties.

40. There are many areas where knowledge is still very limited.

41. There is very limited understanding among stakeholders of geoengineering concepts, techniques and their potential positive and negative impacts on biodiversity.

***Key message from Technical Series No. 66 Part II:*** *The Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity (Bodle et al, 2012)*

42. The Conference of the Parties to the Convention on Biological Diversity, taking into account *the possible need for science based global, transparent and effective control and regulatory mechanisms*, requested a study to be undertaken on gaps in such existing mechanisms for climate-related geoengineering relevant to the Convention on Biological Diversity

43. "Climate-related geoengineering" is a general term that encompasses several different geoengineering concepts, techniques or technologies.

44. The need for science-based global, transparent and effective control and regulatory mechanisms may be most relevant for those geoengineering concepts that have a potential to cause significant adverse transboundary effects, and those deployed in areas beyond national jurisdiction and in the atmosphere.

45. The existing regulatory framework includes general customary rules of international law and specific international treaties.

*General rules of customary international law*

46. State responsibility describes the rules governing the general conditions under which a State is responsible for wrongful actions or omissions, and the resulting legal consequences.

47. All States are under a general obligation to ensure that activities within their jurisdiction or control respect the environment of other States or of areas beyond national jurisdiction or control.

48. States have the duty to carry out an environmental impact assessment for activities that may have a significant adverse impact in a transboundary context, in particular, on a shared resource.

49. The precautionary principle or approach is relevant but its legal status and content in customary international law has not yet been clearly established, and the implications of its application to geoengineering are unclear.

50. Other relevant general concepts include sustainable development, common but differentiated responsibilities, and concepts addressing international interest in the protection of areas beyond national jurisdiction and shared resources as well as issues of common concern such as biodiversity.

*Specific treaty regimes and institutions*

51. The Convention on Biological Diversity has adopted a decision on geoengineering that covers all technologies that may affect biodiversity.

52. The United Nations Convention on the Law of the Sea (UNCLOS) sets out the legal framework within which all activities in the oceans and seas must be carried out, including relevant geoengineering activities.

53. The London Convention and its Protocol (LC/LP) have provided detailed guidance on ocean fertilization, as well as carbon storage, and are considering wider application to other marine geoengineering activities within their mandate. Disposal of CO2 in the water column or on the seabed is not allowed under the London Protocol.

54. The UNFCCC and Kyoto Protocol have not addressed geoengineering concepts as such or its governance.

55. The Vienna Convention for the Protection of the Ozone Layer requires Parties, inter alia, to take measures to protect human health and the environment against likely adverse effects resulting from human activities that modify or are likely to modify the ozone layer. The Montreal Protocol requires Parties to phase down certain substances that deplete the ozone layer.

56. The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) would only apply directly to geoengineering if it were used as a means of warfare.

57. The deployment of shields or mirrors in outer space to reflect or block solar radiation would fall under Space Law.

58. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) prohibits CO2 storage in the water column or on the seabed and has developed rules and guidance for the storage of CO2 in geological formations under the seabed.

59. The Convention on Long Range Transboundary Air Pollution (LRTAP) may be relevant for geoengineering concepts such as aerosol injection, which introduce sulphur or other substances into the atmosphere.

60. Human rights law would be relevant if a particular geoengineering activity violates specific human rights.

61. International institutions such as the United Nations General Assembly, United Nations Environment Programme (UNEP), World Meteorological Organization (WMO) and Intergovernmental Oceanographic Commission (IOC) of UNESCO are relevant to the governance of geoengineering.

62. Research is generally not specifically addressed under international law as distinct from the deployment of technology with known impacts or risks, apart from special rules in certain areas.

*Gaps in the current regulatory framework*

63. The current regulatory mechanisms that could apply to climate-related geoengineering relevant to the Convention on Biological Diversity do not constitute a framework for geoengineering as a whole that meets the criteria of being science-based, global, transparent and effective.

64. Some general principles of international law such as the duty to avoid transboundary harm, and the need to conduct an environmental impact assessment (EIA), together with the rules of State responsibility provide some guidance relevant to geoengineering.

65. Some geoengineering techniques are regulated under existing treaty regimes, while others are prohibited:

(a) Disposal of $CO_2$ in the water column or on the seabed is not allowed under the LP.

(b) Ocean fertilization experiments are regulated under the LC/LP's provision on dumping and additional non-binding guidance including a risk assessment framework;

(c) $CO_2$ storage in sub-surface geological formations is regulated under the LC/LP and the OSPAR Convention.

66. Some other geoengineering techniques would be subject to general procedural obligations within existing treaty regimes, but, to date, no specific rules governing these particular techniques have been developed.

67. Most, but not all treaties, potentially provide for mechanisms, procedures or institutions that could determine whether the treaty in question applies to a specific geoengineering activity and address such activities.

68. The lack of regulatory mechanisms for sunlight reflection methods is a major gap, especially given the potential for significant deleterious transboundary effects.

69. Most regulatory mechanisms discussed in the report were developed before geoengineering was a significant issue and, as such, do not currently contain explicit references to geoengineering approaches.